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STRAM - An Air Pollution Model Incorporating Nonlinear Chemistry, Variable Trajectories and Plume Segment Diffusion

Battelle Pacific Northwest Labs, Richland, Wash

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STRAM – AN AIR POLLUTION MODEL INCORPORATING NONLINEAR CHEMISTRY, VARIABLE TRAJECTORIES, AND PLUME SEGMENT DIFFUSION

U.S. ENVIRONMENTAL PROTECTION AGENCY
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Office of Air Quality Planning and Standards
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species is being added to or depleted from the plume with distance. Under the assumptions stipulated above, Q is also equal to the $f(x)$ term appearing in equations (2) and (3). Thus, one can solve for concentration values in any plume if appropriate values of Q are known. Q in turn may be generated by solving the integral equations (5a)--a task that provides the basis for a major portion of the STRAM algorithm.

Solution of (5a) requires mathematical description of Q_i, and a number of additional modeling assumptions are introduced with this step. These will be subdivided into those regarding chemical transformation, precipitation scavenging, and dry deposition in the following text.

Chemical Reaction: The basis for calculating the chemical-reaction component of Q_i is simply the conventional rate expression utilized in chemical kinetics,

$$r_i(x,y,z) = r_i(T,P,h\nu,\ldots,\sigma_k,\sigma_l,\sigma_m\ldots\sigma_N) \quad . \tag{6}$$

Here r_i is interpreted as the rate of gain of pollutant i by chemical reaction in a differential volume element of atmosphere. Since the reaction of component i may depend upon the concentrations of other species, this term serves as a coupling entity between equations (5a).

One should note here that concentrations of real plumes fluctuate in time, and equations (2) and (3) represent averages over these fluctuations. If equation (6) is nonlinear in concentration, then a positive or negative error (depending upon the direction of deviation from linearity) will result in calculation of the transformation term. A fundamental assumption of this modeling effort is that such errors are negligibly small.

Precipitation Scavenging: The basis for calculating the precipitation scavenging component of Q_i is the washout-coefficient concept. Defining the amount of material removed from a differential volume element of plume per unit time by

$$-w_i(x,y,z) = \Lambda_i \sigma_i(x,y,z) \quad , \tag{7}$$

where Λ_i is the washout coefficient, provides a direct means for evaluating this component. One should note here that equation (7) implies the basic modeling assumption of irreversible scavenging.

Dry Deposition: The basis for calculating dry deposition in the present model is the deposition-velocity concept. Here the flux of material delivered to an incremental area of ground surface is

$$F_{d_i}(x,y,0) = v_{d_i}\, \sigma_i(x,y,0) \quad , \tag{8}$$

where v_{d_i} (with units of length/time) is the deposition velocity for plume constituent i.

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ABSTRACT

This document provides a technical description, user's guide and progr- listing for (1) STRAM - a variable trajectory, reactive plume-segment m- for ground level air pollution assessments resulting from multi-source emissions on a multi-state scale, and (2) a supporting program, Random-to-Grid, which generates gridded wind data for STRAM from synoptic wind data at arbitrarily located observing stations.

The advection is defined over a Cartesian grid of which the sampling grid, also Cartesian, is a subset, usually of greater density. There is also provision for further sampling at particularly specified receptor locations.

The reactive plume chemistry is calculated by a Subroutine STRAC and related subroutines, which calculate the diffusion, the wet and dry depletion, and the reactive chemistry within each plume segment.

The formulations of reactive chemistry, of wet and dry plume depletion, of plume rise, and of diffusion will differ for separate applications and can be expected to change as the states of knowledge in each of these areas evolve. Therefore, STRAM isolates each of these calculations in individual subroutines so that the user can easily effect timely modifications of the code as is deemed appropriate.

STRAM also has provision for time-varying definitions of stability and mixing height. However, the manner of specification and of entry of the data is left to the discretion of the user, notwithstanding the included example.

The principal output of STRAM is concentrations on the sampling grid and at each particularly specified sampling point for each of the analysed chemical components. These are available for three averaging periods (1) once for the entire running time, (2) serially for the basic sampling interval, and (3) serially for an arbitrarily specified intermediate time. Matrices of maximum values over all matrices of this last type are also printed out.

Output is made to magnetic tape of all matrices averaged over the basic sampling interval and of such input parameterisation as is essential to interpret the results of the run.

CONTENTS

ABSTRACT iii

FIGURES vi

TABLES vii

ACKNOWLEDGMENTS viii

I. INTRODUCTION 1

II. TECHNICAL DISCUSSION 3

A. Plume Chemistry and Dispersion 3

1. Theory of Basic Equations 3

2. Finite Difference Approximation 8

3. Examples of Applicability 11

B. Trajectory Analysis 12

1. Grid Definitions 12

2. Theory of Basic Equations 15

3. Approximation of the Wind Integral by Finite Summation 16

4. Examples of Application 19

C. Calculation of Input Parameters 19

1. Preparation of Data for Calculation of Trajectories . . 19

2. Calculations of Plume Chemistry and Dispersion Data 19

III. USER'S GUIDE 25

A. INTRODUCTION 25

1. General Data Processing Requirements 25

2. STRAH System Flow Chart 25

CONTENTS (Cont.)

B. RANDOM-TO-GRID 45

1. Description, Function, Constraints 45

2. Flow Diagram - Major Functions 47

3. Executive Control Language and Deck Setup. 49

4. Input Description and Formats. 50

5. Output Description and Formats 55

6. Diagnostic Messages. 56

C. STRAH PROGRAM 56

1. Description, Functions and Constraints 56

2. Flow Diagram - Major Functions 58

3. Executive Control Language and Deck Setup. 58

4. Input Description and Formats. 54

5. Output Description and Formats 60

6. Diagnostics. 62

IV. INSTALLATION - TEST RUN. 65

A. Random-to-Grid Test Run 65

1. Input Data 65

2. Output Data. 71

B. STRAH Test Run 91

1. Input Data 91

2. Output Data. 95

V. SOURCE PROGRAH LISTINGS. 106

VI. REFERENCES 140

VII. GLOSSARY 141

VIII. ADDENDA. 147

FIGURES

1	Plume Increments and Segments From Two Sources	1
2	Schematic Illustration of Mass Balance Principle	3
3a	Portion of Truncated 47 x 47 NMC Grid Used in Establishing Coordinate System for STRAM. The Origin in This System Has Been Shifted to the North Pole.	14
3b	Expanded View of the Box in Figure 3a.	14
4	Theoretical Trajectories Step.	15
5	Two-step Approximation of Trajectory Step.	17
6	Washout Coefficients for Size Codistributed Aerosols	21
7	System Flow Chart.	26
8	Random-to-Grid Flow Diagram - Major Functions.	28
9	Truncated NMC Grid, Used as a Basis for Interpolation Grid Positioning on Input Card #5 to RNORD	33
10	Flow Diagram for Subroutine STRAC.	43
11	Flow Diagram for Subroutine INTORT	46
12	Schematic Illustration of Plume as Seen in Subroutine SAMPLE	50
13	Flow Diagram of the Major Functions of STRAM	53

TABLES

1	Forms of the Washout and Dry Deposition "Generation" Integrals in Equation 9	7
2	Base Points and Weighting Factors for Ten-Point Gauss-Laguerre Integration	4
3	Suggested Reaction Rate Parameters	20
4	Coefficients for Dispersion Parameters Formulas	24
5	Card Input Descriptions	30
6	Wind Data Tape Input Description	34
7	Card Input Description for STRAM	55
8	Card Input for Test Run of Random-to-Grid	65
9	Card Input for Test Run of STRAM	91

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The wind-field portion of the plume model described in this report is an expansion of an original scheme developed by Dr. L. L. Wendell of Battelle-Northwest. The authors express their sincere appreciation to Dr. Wendell for his helpful guidance and suggestions given during the course of this project.

SECTION I

INTRODUCTION

STRAM (Source-Transport-Receptor Analysis Model) is a user-oriented computer program that provides computed estimates of concentrations and removal rates in airborne, multicomponent, reactive plumes. A multiple source capability is provided, thus allowing calculations, at points on a regional-scale map, of ground-level concentrations which have arisen from a superimposition of a number of plumes originating at different geographical locations.

At the outset it is important to observe that STRAM provides calculated plume distributions that pertain to a given instant of time. They would correspond, for example, to a snapshot taken from a satellite of plumes on the earth's surface below. A visual portrayal of such computed distributions is shown in Figure 1, which (for this example) is a view of the plumes divided into plume segments.

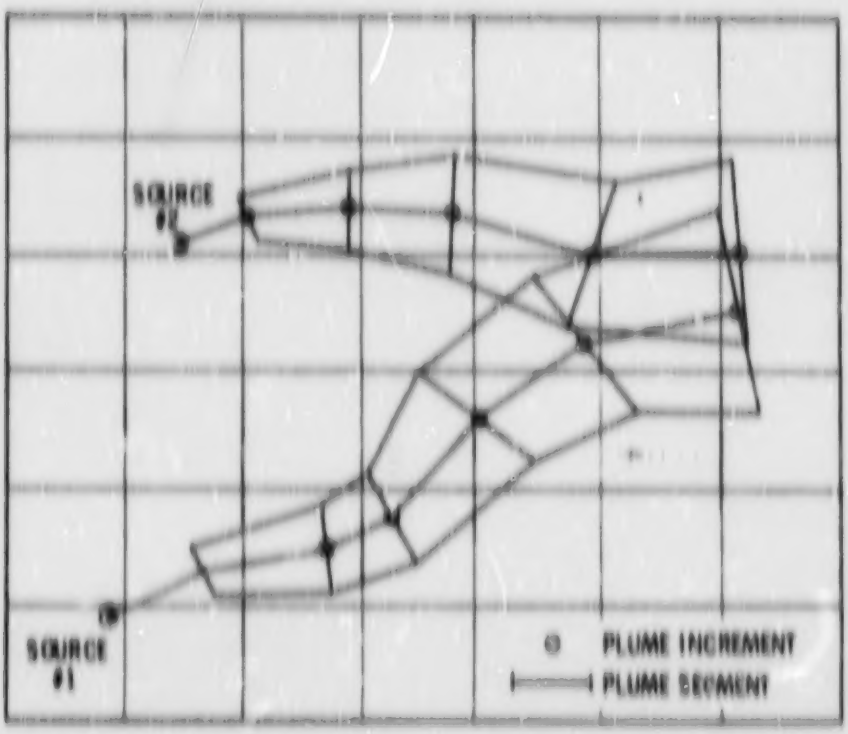


Figure 1. Plume increments and segments from two sources

Such distributions can be computed for successive increments of time, and a time series of these distributions can be averaged to obtain climatological pollutant concentration distributions.

The workings of STRAM consist of three major routines; 1) a trajectory routine that calculates trajectories of plume increments over the regional-scale area using historical gridded wind data, 2) a dispersion routine that calculates dispersion parameters, wet and dry removal, and transformation of mass within each plume by chemical processes, 3) a sampling routine that interpolates plume concentrations to grid intersections and other specified locations.

The output of STRAM to line printer and magnetic tape consists of concentrations averaged over specified time intervals and certain maxima over these time intervals.

SECTION II

TECHNICAL DISCUSSION

A. PLUME CHEMISTRY AND DISPERSION

1. Theory of Basic Equations

The fundamental basis for the STRAH plume model is an integral material balance over a finite volume element of plume, as indicated in Figure 2. Denoting pollutant concentration by c and the wind speed in the downwind direction by u, one can represent the fluxes of pollutant into and from the represented volume element :y

$$\int_0^{\infty}\int_{-\infty}^{\infty} uc\, dy\, dz\Big|_x \quad \text{and}$$

$$\int_0^{\infty}\int_{-\infty}^{\infty} uc\, dy\, dz\Big|_{x+\Delta x} \quad \text{respectively.}$$

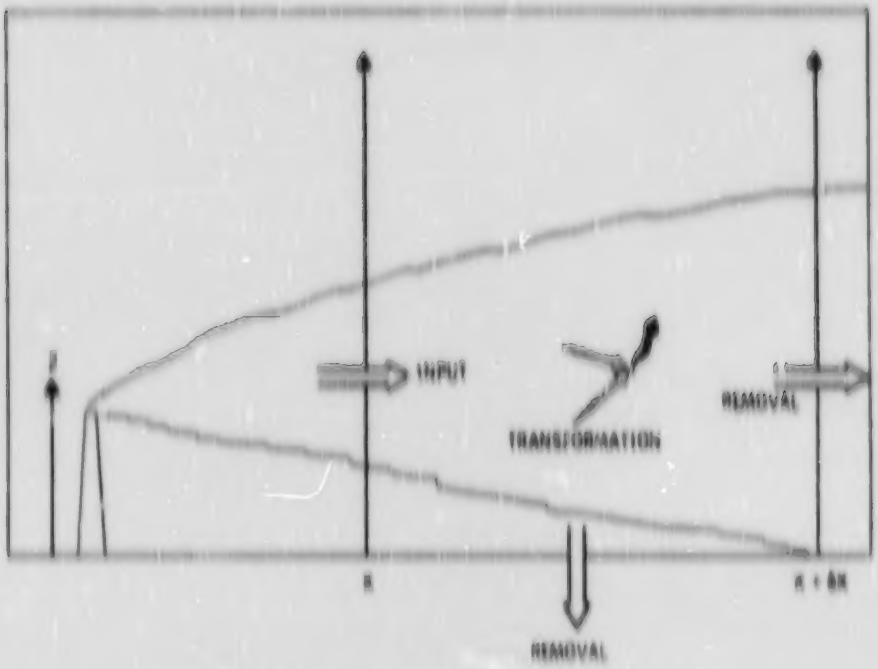


Figure 2. Schematic illustration of mass balance principle

The rate of gain* of pollutant in the volume element by reaction and deposition processes will be denoted here by the term G**. Although a number of mechanisms can act to deplete or generate material, it is appropriate at this point simply to lump them into a single term, which can be disaggregated later as desired. The rate of gain of material by reaction, washout, and dry deposition can be described by the term

$$\int_0^{\infty}\int_{-\infty}^{\infty} G(x,y,s)\,dy\,ds\,\delta x \quad .$$

Since the time rate of change of pollutant abundance in the volume element is equal to the sum of contributions by the above mechanisms, one can perform a fundamental material balance to obtain the following expression:

$$\frac{\partial}{\partial t}\int_0^{\infty}\int_{-\infty}^{\infty} c\,dy\,ds\,\delta x = \text{time rate of change of pollutant mass in macroscopic volume element}$$

$$= \int_0^{\infty}\int_{-\infty}^{\infty} uc\,dy\,ds\Big|_x - \int_0^{\infty}\int_{-\infty}^{\infty} uc\,dy\,ds\Big|_{x+\delta x}$$

$$+ \int_0^{\infty}\int_{-\infty}^{\infty} G(x,y,s)\,dy\,ds\,\delta x \quad . \qquad (1)$$

Equation (1) is directly extendable to multicomponent systems simply by subscripting c and G (c_i, i=A,B,C,..,N; G_i, i=A,B,C,..,N where i is a pollutant species index), and writing N simultaneous equations of the form (1) for the n components existing in the plume.

One should note that equation (1) is highly general, its primary precepts being those of mass conservation and differential calculus.

We now shall proceed to limit this generality by imposing a number of stipulations, which are itemized as follows:

- A quasi-steady state exists, where the left-hand side of (1) can be set equal to zero, at least for short intervals of time.

*Note that loss is a negative "gain." The sign convention will be used that denotes gain of material as a positive entity.

**G has units of mass/length^3-time.

- The shapes of the concentration profiles are known. We will consider two cases at present; these are where the concentration profiles follow (1) a bivariate-normal form, given by

$$c = \frac{f(x)}{2\pi\sigma_y\sigma_z u} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \left\{\exp\left[-\frac{(z-h)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+h)^2}{2\sigma_z^2}\right]\right\} \qquad (2)$$

and (2) a limited mixing height form, given by

$$c = \frac{f(x)}{\sqrt{2\pi}\, u\, H\sigma_y} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \qquad (3)$$

- The wind profile is uniform vertically, and does not change appreciably in the interval $(x, x+\delta x)$.

Applying the above assumptions and taking limits in x in the conventional manner, one obtains the simpler form

$$\frac{d}{dx}\left\{u\int_0^\infty\int_{-\infty}^{\infty} c\, dy\, dz\right\} = \int_0^\infty\int_{-\infty}^{\infty} S(x,y,z)\, dy\, dz. \qquad (4)$$

Now, since c (or at least its profile shape) is known and integrable, one can express the bracketted term in equation (4) as an algebraic quantity. Thus,

$$\frac{dQ}{dx} = \int_0^\infty\int_{-\infty}^{\infty} S(x,y,z)\, dy\, dz \quad , \qquad (5)$$

or, in the multicomponent case,

$$\frac{dQ_i}{dx} = \int_0^\infty\int_{-\infty}^{\infty} S_i(x,y,z)\, dy\, dz, \; i=A,B,C,\ldots,N \quad . \qquad (5a)$$

$Q = \int_0^\infty\int_{-\infty}^{\infty} u\, c\, dy\, dz$ may be interpreted physically as the amount of material in the plume passing a downwind point per unit time. At $x=0$, or, for plumes where $h=0$, this is simply the source strength. Under other conditions Q may be visualised as a "virtual" source strength, which may increase or decrease with distance downwind from the source depending upon whether the pollutant

The mathematical approach utilized by the NTRAC algorithm is to evaluate the integral terms in (8a) prior to solving the differential equation in x. From 6, 7, and 8, one obtains

$$\int_0^\infty \int_{-\infty}^{\infty} q_i(x,y,z)\, dy\, dz\Big|_x = \int_0^\infty \int_{-\infty}^{\infty} r_i(x,y,z)\, dy\, dz +$$

$$\int_0^\infty \int_{-\infty}^{\infty} -\Lambda_i\, q_i(x,y,z)\, dy\, dz + \int_{-\infty}^{\infty} -v_{d_i}\, q_i(x,y,0)\, dy \quad . \qquad (9)$$

Since $r_i(x,y,z)$ depends upon concentration in a manner that may be rather complicated, this model utilizes a numerical technique for evaluation of the integral. The corresponding terms for washout and dry deposition may be evaluated directly by formal integration in conjunction with equations (2) and (3). The results of these integrations are given in Table 1.

TABLE 1. FORMS OF THE WASHOUT AND DRY DEPOSITION "GENERATION" INTEGRALS IN EQUATION 9.

	Bivariate normal	Limited mixing height
Washout	$-\frac{\Lambda_i\, Q_i}{u}$	$-\frac{\Lambda_i\, Q_i}{u}$
Dry Deposition	$-\sqrt{\frac{2}{\pi}}\,\frac{Q_i\, v_{d_i}}{\sigma_z u}\, \exp\left(\frac{-h^2}{2\sigma_z^2}\right)$	$-\frac{Q_i\, v_{d_i}}{u\, H}$.

8. Finite Difference Approximations

As indicated above, finite differencing techniques are employed by the STRAC algorithm to approximate the reaction-rate integral in equation (9), and also to evaluate the a dependencies of Q_i in equations (8a). The first of these applications, i.e., that of evaluating the integral

$$I_{r_i} = \int_0^{\infty} \int_{-\infty}^{\infty} r_i(s,v,s)\, dv\, ds \quad , \tag{10}$$

is accomplished in a straightforward manner using a ten-point Gauss-Laguerre quadrature:

$$\int_0^{\infty} e^{-\xi} f(\xi)\, d\xi \approx \sum_1^{10} w_i\, f(\xi_i) \quad . \tag{11}$$

Here the ξ_i are selected values of the independent variable and the w_i are weighting factors, as shown in Table 3. The expected error from this approximation technique is

$$\varepsilon = 5.4 \times 10^{-9}\, \frac{d^{20} f(\xi)}{d\xi^{20}} \quad , \ \xi \text{ in } (0,\infty) \quad . \tag{12}$$

TABLE 3. BASE POINTS AND WEIGHTING FACTORS FOR TEN-POINT GAUSS-LAGUERRE INTEGRATION

Independent variable base points ξ_i	Weighting factors w_i
0.13779 34705 40	0.30844 11157 65
0.72945 45494 03	0.40111 99291 55
1.80834 29017 40	0.21806 82876 12
3.40143 36978 55	$0.62087\ 45609\ 87 \times 10^{-1}$
5.55249 61400 64	$0.95015\ 16975\ 18 \times 10^{-2}$
8.33015 27467 64	$0.75300\ 03885\ 88 \times 10^{-3}$
11.84378 58379 00	$0.28259\ 23349\ 60 \times 10^{-4}$
16.27925 78313 78	$0.42493\ 13084\ 96 \times 10^{-6}$
21.99658 58119 81	$0.18395\ 64823\ 98 \times 10^{-8}$
29.92069 70138 74	$0.99118\ 27319\ 61 \times 10^{-12}$

Equation (10) is evaluated using (11) as follows: First, the y and z extents of the plume are scaled so that the primary portions of the plume profile are well covered by the independent variable points ξ_i given in Table 3. $F_1(x,y,z)$ is then multiplied by the factor e^{y} to compensate for its reciprocal term in (11), and the resulting function is integrated over y at each chosen level of z (dictated by ξ_i). The ten values of the y integral resulting from this operation are then doubled (to reflect the fact that the limits for the y integration are $(-\infty, \infty)$ rather than $(0,\infty)$, and are used as base points for a second integration in the z-direction. In applying (11) for this final integration the base functions once again are premultiplied by e^{z} to compensate for its reciprocal in the integral.

Values for y and z are scaled for the numerical quadrature in a somewhat arbitrary manner to provide good coverage of the plume by the independent integration variable ξ, whose base points (note Table 3) range approximately between zero and thirty. In the y-direction we let

$$\xi = \frac{6y}{\sigma_y} \quad , \tag{13}$$

thus,

$$I_y(z) = \int_0^\infty e^{-y} F(y)\, dy = \frac{\sigma_y}{6} \int_0^\infty e^{-\xi} F(\xi)\, d\xi \quad , \tag{14}$$

$$\left(F(y) = e^{y} F_1(x,y,z)\right)$$

For the z-direction we let

$$\xi = \frac{2z}{\sigma_z} + 15 = \frac{2h}{\sigma_z} \tag{15}$$

unless $h < 5\sigma_z$, in which case we let

$$\xi = \frac{2z}{\sigma_z} \tag{16}$$

These transformations provide the integral representations

$$I_{F_1} = \int_0^\infty e^{-z} H_y(z)\, dz = \frac{\sigma_z}{2} \int_0^\infty e^{-\xi} H_y(\xi)\, d\xi \quad , \tag{17}$$

$$\left(H_y = e^{z} I_y(z)\right) \quad .$$

Scaling y and z using (13), (15), and (16), integrating using (11), and then descaling using (14) and (17) allows the integral (10) to be approximated in a relatively straight-forward manner.

Once the integral I_{z_i} is evaluated it may be added to the appropriate entries of Table I to obtain the total integral in equation (5a). For a bivariate-normal plume this is

$$I_{t_i} = I_{z_i} - \frac{A_i Q_i}{u} \sqrt{\frac{2}{\pi}} \frac{Q_i V_{d_i}}{\sigma_z u} \exp\left(\frac{-h^2}{2\sigma_z^2}\right) \quad , \tag{18}$$

For the limited mixing-height case, it is given by

$$I_{t_i} = I_{z_i} - \frac{A_i Q_i}{u} - \frac{Q_i V_{d_i}}{u H} \quad , \tag{19}$$

This effectively reduces the integro-differential equations (5a) into differential equations of the form

$$\frac{d Q_i}{d x} = I_{t_i}(x) \quad , \tag{20}$$

The STRAC algorithm generates finite-difference approximations to solutions of equation (20) using a second-order Runge-Kutta technique. This technique utilizes an initial condition

$$Q_i = q_i \quad \text{at} \quad x = 0 \quad , \tag{21}$$

plus a derivative evaluation at $x = 0$, to estimate a derivative

$$f_{\Delta x} \approx \left.\frac{dQ_i}{dx}\right|_{\Delta x/2}$$

at the half-interval step $\Delta x/2$. This value is then utilized with condition (21) to provide an estimate of Q_i at $x = \Delta x$:

$$\left.Q_i\right|_{\Delta x} \approx \left.Q_i\right|_{0} + \Delta x \; f_{\Delta x} \quad . \tag{22}$$

Values of Q_i at larger x are generated by repeating this procedure. The initial condition (21) simply is replaced by the derived value of Q_i at the last point of calculation, and the process is continued until the desired downwind distance

is attained. The fractional truncation error[1] associated with this method is of the order of

$$\left(\frac{\Delta x_{int}}{x_{tot}}\right)^2$$

where x_{tot} is the total downwind distance covered by the integration.

In summary, the numerical procedure utilized to generate solutions to equations (5a) follows the following sequence:

1. Evaluate the double integral in equation (10) using a double application of the Gauss-Laguerre quadrature. Repeat for all components in the system.

2. Integrate differential equation (20) for one step in the x-direction using the second-order Runge-Kutta algorithm. Repeat for all components in the system.

3. Repeat steps 1 and 2 until the desired downwind distance has been attained. Generate ground-level concentration values as desired using equations (2) and (3) in conjunction with the computed values of Q_i.

3. Examples of Applicability

The plume model described in the previous text is applicable to a wide variety of situations. In addition to being useful as a single-source model for predictive and diagnostic purposes, it can be utilized as a multiple source descriptor. When combined with descriptions of wind fields and other meteorological parameters, this model can be utilized to provide concentrations, at points on a map, arising from multicomponent, reactive plumes originating at a variety of source locations. The following sections describe how this combination is accomplished within the framework of this overall modeling scheme.

[1] Expressed as the fraction of the maximum value of Q.

B. TRAJECTORY ANALYSIS

1. Grid Definitions

Horizontal trajectories are computed in time segments of equal length Δt using a series of gridded wind fields. The various grids to be defined are all derived from the NMC 47 by 47 octagonal grid. A portion of this grid is in Figure 3a.

The NMC grid map is a polar stereographic projection of an octagonal area centered about the north pole and extended sufficiently that all the northern hemisphere north of the 10th parallel is included. Some of the equations pertaining to the map are as follows. Let R be the radius in NMC grid units from the north pole to a point on the map at latitude ϕ (radians). The equations relating R and ϕ are:

$$R = 31.184 \frac{\cos \phi}{1 + \sin \phi} \quad , \tag{23}$$

$$\phi = \frac{\pi}{2} - 2 \tan^{-1} \frac{R}{31.184} \quad . \tag{24}$$

The polar stereo projection is such that a basic grid interval

$$\Delta = 3.81 \times 10^7 \text{ cm} \tag{25}$$

is defined as the interval at 60°N between consecutive grid intersections. At any latitude the grid interval is given by

$$D = \Delta / \Phi \tag{26}$$

where Φ is the polar stereo map factor given by

$$\Phi = \frac{1 + \sin (\pi/3)}{1 + \sin \phi} \quad . \tag{27}$$

There are three grids to be defined on the NMC grid--the original grid, the advection grid, and the sampling grid. The original grid is a rectangular portion of the NMC 47 by 47 grid, arbitrarily selected by the user. The advection grid is either identical to the original grid or formed by some integral subdivision of it. The advection grid is identical to that used for defining the wind field. The sampling grid is defined as a rectangular subset of the advection grid, independently subdivided.

Let I_a be an arbitrary positive integer selected as the ratio of the spacing on the original grid to that on the advection grid. For example if I_a is 2, the change of coordinates over any given line common to the two grids will be twice as great in the coordinate system of the advection grid as in that of the original grid.

let F_a be an arbitrary floating point number selected as the ratio of spacing on the advection grid to that on the sampling grid. Using D defined by (36) we can write the expression for the grid intervals as functions of latitude on the advection grid and on the sampling grid. We have

$$D_a = D/I_a \ , \tag{38}$$

$$D_s = D_a/F_a \ , \tag{39}$$

for grid intervals on the advection and sampling grids, respectively. The latitude dependence comes from the map factor in D. Let the X and Y direction within the advection grid be defined as the horizontal and vertical directions, respectively, on the NMC grid. In this case, the X direction is approximately west-east over the U.S., exactly so, at 80°W longitude. There are three right-handed coordinate systems to be considered within the original grid--one for each of the previously named grids. For the coordinate system of the NMC grid, we will consider the origin to be at the pole.* The negative Y axis extends downward across North America at longitude 80°W. Over North America, the X coordinates are negative west of 80°W, and positive east of 80°W. Therefore, all grids selected over the United States will have negative Y coordinates in this system, and most would have either zero or negative X coordinates for the left margin. This coordinate system is used only in one read statement to identify the advection grid on the NMC grid. No other input, and no gridded output is in this coordinate system. The advection grid assigns the origin to the lower left corner of the advection grid. The numbering of the X and Y axis is in increments of D_a.

The sampling grid is a subset of the advection grid. The origin may be at any point on the advection grid, other than those on the upper or right boundaries. The numbering of the X and Y axes is in increments of D_s.

An enlargement of the three grids is shown in Figure 3b. The heavy lines are lines connecting the NMC grid points. They mark off the unit distance D on the NMC grid and on the original grid. The lighter solid lines together with the heavy lines mark off the unit distance on the advection grid for which $I_a = 3$, i.e., 3 units D_a on the advection grid equal one unit D on the original grid. The dashed lines together with the solid lines mark off the unit distance on the sampling grid for which $F_s = 4$.

The coordinate designation (-3,-16) is the coordinates on the NMC grid of the origin of the advection grid. Similarly the coordinate designation (1,-13) is the coordinates on the NMC grid of the upper right corner of the advection grid. The numbers 0 through 8 along the lower and left edges are the scale in the advection grid system.

The sampling grid has its lower left and upper right corners at (1,1) and (4,4), respectively, on the advection grid.

*Note difference between this and coordinate definitions for the same grid in Random-to-Grid, see Figs. 3a, 9.

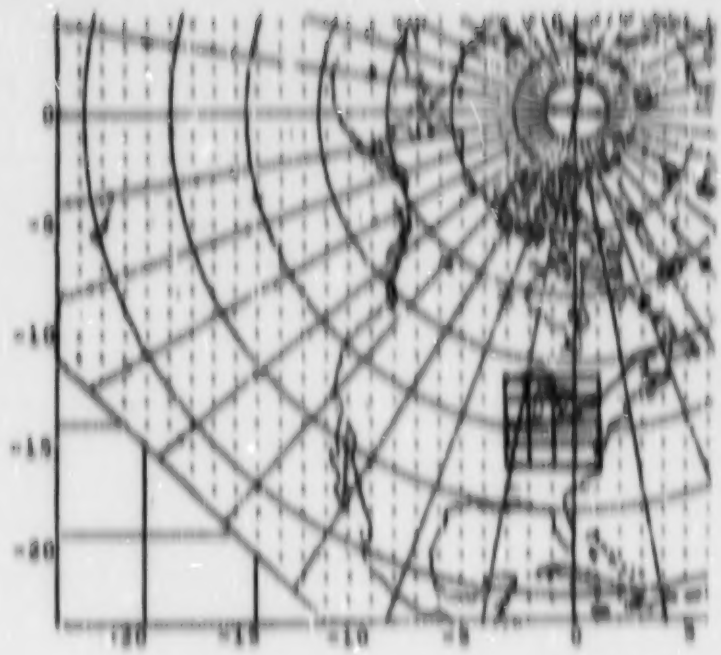


Figure 1a. Portion of truncated 47 x 47 NMC grid used in establishing coordinate system for STRAM. The origin in this system has been shifted to the North Pole

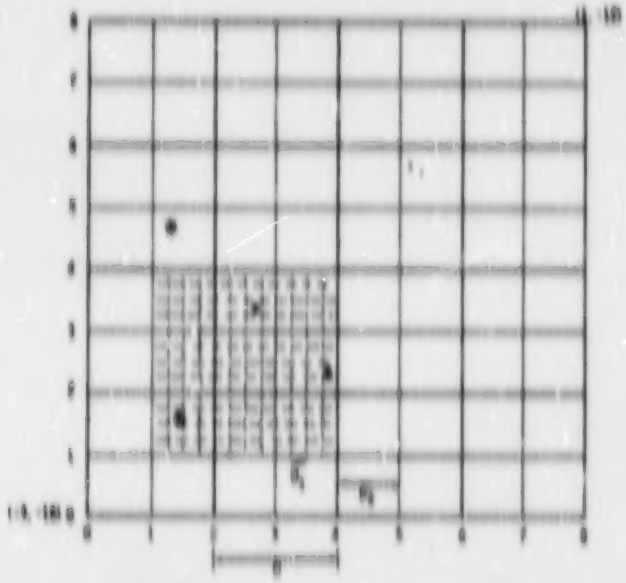


Figure 1b. Expanded view of the box in Figure 1a

The stars are source locations. The dots in the sampling grid are particularly specified sampling locations. The numbers in parentheses are coordinates on the NMC grid.

8. Theory of Basic Equations

Let the horizontal projection of a portion of a trajectory over one square of the advection grid be as in Figure 4. Assume that the curved line between the two dots is the horizontal projection of the path of advection during the interval Δt. The change of coordinates due to advection over the directed distance Δs is expressed by resolving it into the components in the X and Y directions. Specifically over the interval Δt, the components of the advection are:

$$\Delta X = \frac{\Delta}{D_s} \int_{t_1}^{t_1+\Delta t} U(t') \cos\alpha(t')dt' \quad , \tag{30}$$

$$\Delta Y = \frac{\Delta}{D_s} \int_{t_1}^{t_1+\Delta t} U(t') \sin\alpha(t')dt' \quad , \tag{31}$$

where $U(t')$ is the horizontal wind speed. D_s is used to convert the advection components from the length units of U to length units on the advection grid.

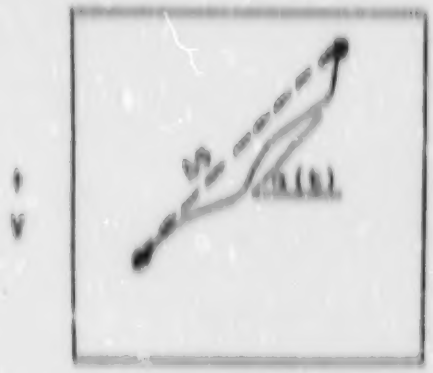


Figure 4. Theoretical trajectories step

Let the components of the wind in the X and Y direction along the trajectory be designated by

$$U(t;X(t),Y(t))$$

$$V(t;X(t),Y(t)), \text{ respectively.}$$

The capital letters are used to distinguish these wind directions from those used in Subroutine SPRAC, which are parallel and lateral to the mean path of advection rather than being aligned with the grid. Then the increments of advection over a time Δt are given by

$$\Delta X = \frac{1}{D_a} \int_{t}^{t+\Delta t} U(t';X(t'),Y(t'))dt' \quad , \tag{32}$$

$$\Delta Y = \frac{1}{D_a} \int_{t}^{t+\Delta t} V(t';X(t'),Y(t'))dt' \quad , \tag{33}$$

After the new coordinates $X(t+\Delta t)$ and $Y(t+\Delta t)$ are calculated for each increment of a given plume, a check is made to see if any of these values are off the grid. If so, not only the affected plume increment, but the entire portion of the plume emitted before the emission time of the affected increment is deleted from further consideration.

1. Approximation of the Wind Integral by Finite Summation

The integration of the wind components over the trajectory is approximated by a two-step iteration method involving bilinear interpolation in space and in time (see Figure 5).

The various positions in Figure 5 are here defined by equations:

$$X_1 = X(t) + U(t;X(t),Y(t))\Delta t \quad , \tag{34}$$

$$Y_1 = Y(t) + V(t;X(t),Y(t))\Delta t \quad , \tag{35}$$

$$X_2 = X_1 + U(t+\Delta t;X_1,Y_1)\Delta t \quad , \tag{36}$$

$$Y_2 = Y_1 + V(t+\Delta t;X_1,Y_1)\Delta t \quad , \tag{37}$$

$$X(t+\Delta t) = 0.5(X(t) + X_2) \quad , \tag{38}$$

$$Y(t+\Delta t) = 0.5(Y(t) + Y_2) \quad . \tag{39}$$

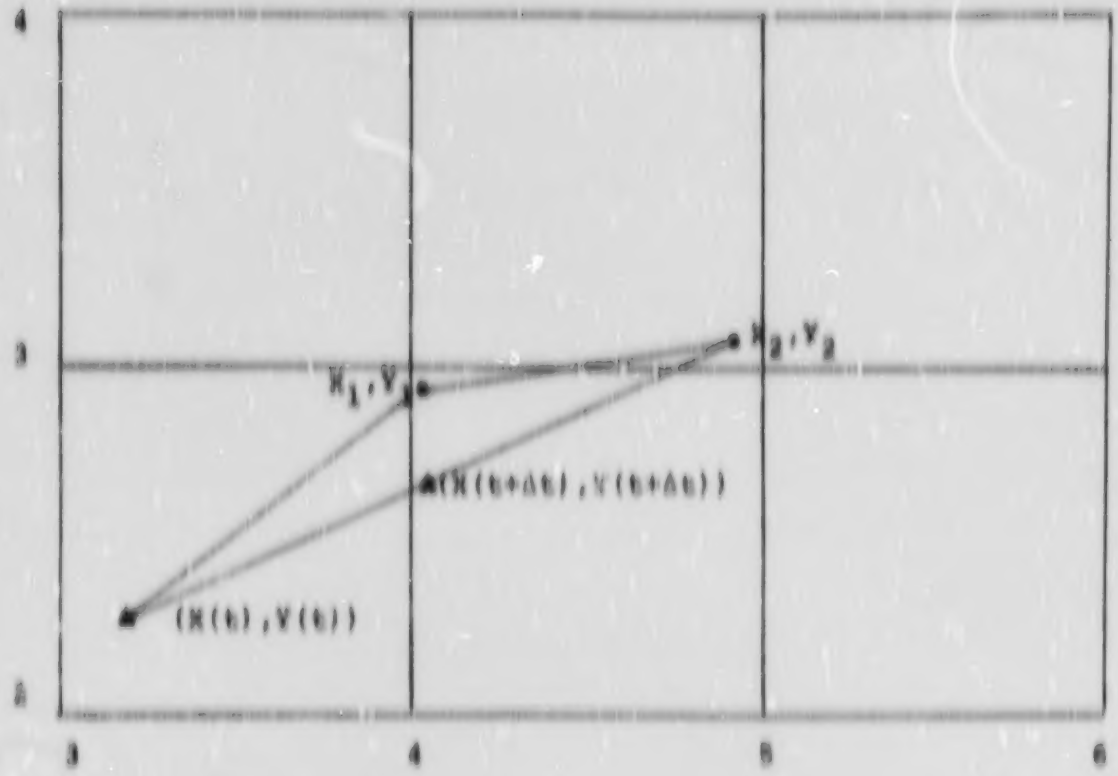


Figure 5. Two-step approximation of trajectory step

Thus, the new position (X(t+Δt),Y(t+Δt)) is found by adding the vector average of two advection increments to the former position (X,t),Y(t)). The first advection increment is calculated by advecting the plume increment for the entire interval Δt using the wind effective at X(t),Y(t) at time t. The addition of this increment to the position (X(t),Y(t)) yields the position (X_1,Y_1). However, (X_1,Y_1) is not assumed to be the actual end of the advection increment because the wind may change along the trajectory. To correct, at least to some degree, for this situation, a second advection increment is calculated using (X_1,Y_1) as the starting point and the wind at that point effective at the end of the time increment. The addition of this advection increment to position (X_1,Y_1) yields position (X_2,Y_2). Then the new plume increment position (X(t+Δt),Y(t+Δt)) is taken to be halfway along the line from (X(t),Y(t)) to (X_2,Y_2).

The bilinear interpolation by which the effective wind components U(t), and V(t) are calculated works as follows. Let t_m and t_{m+1} be the effective times of the two wind maps closest to time t. Time interpolation weights t_1 and t_2 are defined by

$$t_2 = \frac{t - t_m}{t_{m+1} - t_m} \quad , \qquad t_m \le t < t_{m+1} \quad , \tag{40}$$

$$t_1 = 1 - t_2 \quad , \tag{41}$$

Next, we note the location of (X(t),Y(t)) on Figure 5. The coordinate values are between 3 and 4 for X(t) and between 2 and 3 for Y(t). Accordingly, we define:

$$X_q = X(t) - 3 \quad , \tag{42}$$

$$X_p = 1 - X_q \quad , \tag{43}$$

$$Y_q = Y(t) - 2 \quad , \tag{44}$$

$$Y_p = 1 - Y_q \quad , \tag{45}$$

This yields

$$\begin{aligned} U(t) = {} & t_1 X_p Y_p \, U(t_m,3,2) + t_2 X_p Y_p \, U(t_{m+1},3,2) \\ & + t_1 X_q Y_p \, U(t_m,4,2) + t_2 X_q Y_p \, U(t_{m+1},4,2) \\ & + t_1 X_p Y_q \, U(t_m,3,3) + t_2 X_p Y_q \, U(t_{m+1},3,3) \\ & + t_1 X_q Y_q \, U(t_m,4,3) + t_2 X_q T_q \, U(t_{m+1},4,3). \end{aligned} \tag{46}$$

Similar equations hold for V(t), U(t+Δt), and V(t+Δt).

Therefore the advection equations 32 and 33 are calculated from

$$\Delta X = \frac{1}{20_a} \left[U(t) + U(t+\Delta t) \right] \Delta t \quad , \tag{47}$$

$$\Delta Y = \frac{1}{20_a} \left[V(t) + V(t+\Delta t) \right] \Delta t \quad , \tag{48}$$

The subsequent positions are of course given by

$$X(t+\Delta t) = X(t) + \Delta X \quad , \tag{49}$$

$$Y(t+\Delta t) = Y(T) + \Delta Y \quad , \tag{50}$$

4. Examples of Application

An example of individual trajectories generated by application of a gridded wind field can be found in the paper by L. L. Wendell (1972).[1] The gridded winds are derived by application of a random-to-grid subroutine (see III.B) to the tower data.

C. CALCULATION OF INPUT PARAMETERS

1. Preparation of Data for Calculation of Trajectories

The calculation of trajectories does not depend on the selection of experimentally determined values analogous to those enumerated in II.C.2 for plume chemistry and dispersion calculations. However, it is necessary to specify the location of the advection grid on the NMC grid, and the location of the sampling grid on the advection grid, as well as the scales of the advection and sampling grids. Also, it is necessary to specify the initial hour for the run using the time zone that is used on the wind tape, the duration in hours of the basic advection step, the time interval between printed concentration maps, and the total number of hours in the run. Meteorological data is in Greenwich time (GMT).

Since all these relations are governed by input data that are read in from punch cards prepared by the user, the detailed description necessary for the user is found in III.C.4 on input parameters.

Furthermore, a matrix of map factors must be used to establish the scale on the original grid (and consequently the scales on the other grids) as a function of latitude. However, this is done automatically once the proper punch card input data are prepared.

2. Calculations of Plume Chemistry and Dispersion Data

a. Chemical Reaction Rates

The rates of SO_2 transformation in plumes have been discussed in detail in a previous report.[4] From this review, it is apparent that the wide variety of conversion rates observed to date cannot be correlated in any simple or straightforward manner. Moreover, our level of understanding at the present time does not justify incorporation of anything more complex than linear kinetics parameterizations, at least for routine calculations.[5]

The previous review indicates that it is expedient to segregate oxidation rates into rather broad condition classes, which are based upon meteorological circumstances and ambient pollutant levels. Table 1 presents a summary of

[5] It should be noted here that research currently in progress is expected to change this situation markedly within the next two years, by providing more reliable parameterizations which are likely to be nonlinear in character.

TABLE 3. SUGGESTED REACTION RATE PARAMETERS

Condition class	Conversion rate %/hr	Rate constant sec^{-1}
Dry nighttime or daylight-low hydrocarbon background	1	2.78×10^{-6}
Nighttime or daylight RH > 80%	6	2.22×10^{-5}
Sunny, with high hydrocarbon levels (imbedded in urban plume)	5	1.39×10^{-5}
Recommended overall value for simple modeling purposes	3	8.34×10^{-6}

selected conversion rates, based upon the ranges given in the review, for each condition class. The rate recommended for trial use with the STRAH code is 3%/hr. First-order rate constants appearing in Table 3 are defined by the equation

$$r_{SO_2} = -r_{SO_4} = -k\, c_{SO_2} \quad \left(\text{units are } \frac{\text{moles}}{cm^3\ sec}\right) , \tag{51}$$

In concordance with the code, the units of k are reciprocal seconds. This rate constant is entered into the code directly in subroutine form, as will be described in Section III.

b. Washout Rates

Although wet removal of SO_2 and $SO_4^=$ can occur through a number of mechanisms, it is appropriate for present purposes to lump these into parameterized expressions based simply upon direct, nonreactive uptake of the species by raindrops. For $SO_4^=$ aerosol one can proceed directly by assessing the particle size distribution and applying existing washout theory to determine representative washout coefficients for a number of aerosol and rain spectra, which can be utilized directly for this purpose.[9] One such set of curves, pertaining to washout under general frontal rain conditions, is shown in Figure 6. Using this curve in conjunction with a log-normally distributed aerosol with a mass-median diameter of 0.05 μ and logarithmic standard deviation of 2 (roughly typical of observed sulfate distributions in plumes), one obtains a washout coefficient of

$$\Lambda_{SO_4^=} = 0.0045\, J \quad , \tag{52}$$

where J is the rainfall rate in mm/sec, and Λ is in sec^{-1}.

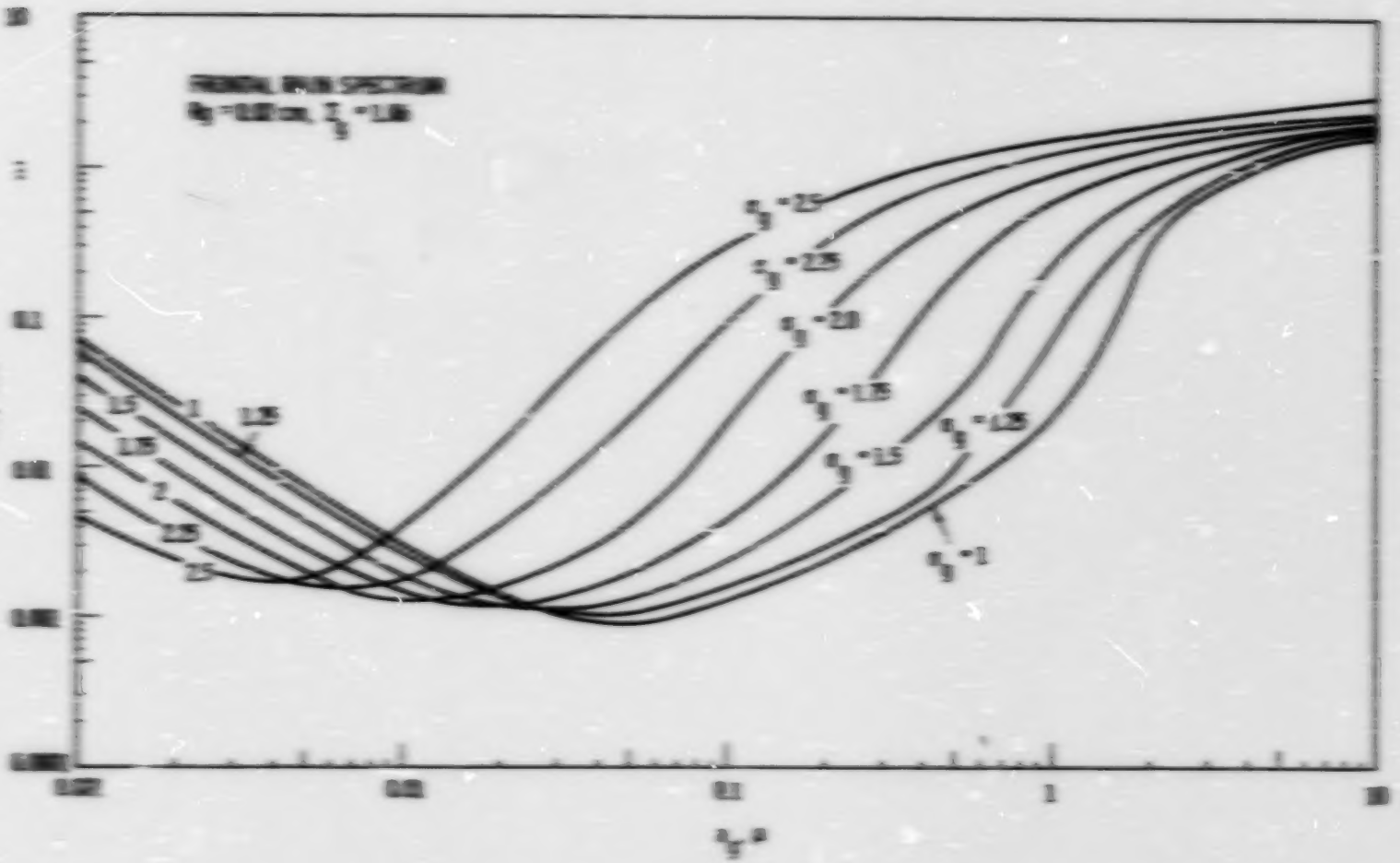


Figure 6. Radiant coefficients for size redistributed aerosols[3]

Although SO_2 washout does not follow the irreversible behavior typical of aerosol removal, an exact treatment of this phenomenon lies beyond the present capabilities of the STRAM code. Because of this, the recommended procedure for estimating SO_2 removal is to apply an effective washout coefficient based upon relative rates of removal observed in past studies of plume washout behavior. These investigations have indicated that, as a rough approximation at points more than a few kilometers downwind from the source,

$$\Lambda_{SO_2} = 0.01 \Lambda_{SO_4^=} \quad (53)$$

Values of the washout coefficients given above can be incorporated by changing Subroutine WSHOUT of the STRAM code, as described in Section III. To utilize these effectively for long-range calculations, however, one must incorporate a spatial and temporal description of rain intensity or climatological averages of the same. Consideration of these spatial and temporal variations is beyond the present capability of the STRAM code. In addition, the current STRAM code assumes that washout rates are equal to zero.

e. Deposition Velocities

Deposition velocities for SO_2 have been observed by a number of investigators to be in the range of 1 cm/sec. The only known measurements of $SO_4^=$ deposition velocities in the real atmosphere have fallen in the range of 0.1 cm/sec.[3] Accordingly, the values

$$V_{d_{SO_2}} = 1 \text{ cm/sec} \quad (54)$$

$$V_{d_{SO_4}} = 0.1 \text{ cm/sec} \quad (55)$$

are recommended for present test calculations. As with previous parameters these are entered directly into STRAM in subroutine form as described in Section III.

f. Plume Rise

For long-range calculations, it is usually most expedient to presume the plume has attained its total effective rise and, rather than burden the user with costly repetitive calculations, STRAM uses the virtual stack height throughout to represent the effective plume height. This height may be changed at regular intervals, typically hourly. The user may wish to rewrite the Subroutine PLMRIS to use Briggs' modified formulas or any of a number of alternative techniques.

g. Stability and Mixing Height

Like virtual stack height, stability and mixing height data may be read in at regular intervals, typically hourly.

f. Calculation of Dispersion Parameters

The dispersion parameters σ_y and σ_z are calculated for distances out to 100 km using analytical formulae derived from the curves in the Workbook of Atmospheric Dispersion Estimates by D. B. Turner.[7] This was a quite straightforward procedure for σ_y since the curves given by Turner on log-log paper are approximately straight lines. For σ_z the Turner curves are not straight lines. However, the curvature is slight enough that good approximations for downstream distances of 1 to 100 km can be made by assuming the curves to be straight lines through the values for those points. Under these conditions extrapolation of the σ_z formulae to distances outside this range is not to be considered. For distances greater than 100 km formulae by Heffter are used.[8]

Since stability changes during real-time dispersion, the formulae to be given below cannot be used as such. If this were done, for example over a time interval when the stability is increasing, the dispersion parameter values would be represented as decreasing functions of time. Therefore, instead of computing from a formulae such as $\sigma_y(s)$ (where s is total travel distance) or $\sigma_y(t)$, the derivative is used as follows:

$$\sigma_y(s+\Delta s) = \sigma_y(s) + \Delta s \left.\frac{d\sigma_y}{ds}\right|_{s+1/2\,\Delta s} , \tag{56}$$

$$\sigma_y(t+\Delta t) = \sigma_y(t) + \Delta t \left.\frac{d\sigma_y}{dt}\right|_{t+1/2\,\Delta t} , \tag{57}$$

Similar equations apply for σ_z.

The integral formulae for σ_y and σ_z for travel distances less than 100 km are of the following forms

$$\sigma_y(s;a) = f_a s^{0.9} \qquad 10^3 m \le s \le 10^5 m , \tag{58}$$

$$\sigma_z(s;a) = f_a s^{b_a} \qquad 10^3 m \le s \le 10^5 m , \tag{59}$$

Here a is a stability index designated as A, B, C, D, E, or F for the Pasquill stability categories. The formulae are not valid if the stability has changed over the travel distance s. The coefficients f_a and b_a yield σ_y and σ_z in meters when s is also measured in meters. They are given in Table 4.

The derivative forms used in carrying out the actual computations are, of course,

$$\frac{d\sigma_y}{ds} = 0.9\, f_a s^{-0.1} \qquad 10^3 m \le s \le 10^5 m , \tag{60}$$

TABLE 4. COEFFICIENTS FOR DISPERSION PARAMETERS FORMULAS

α	γ_α	β_α	b_α
A	0.36	0.00023	2.10
B	0.35	0.058	1.09
C	0.19	0.11	0.91
D	0.11	0.57	0.58
E	0.096	0.85	0.47
F	0.063	0.77	0.42

$$\frac{d\sigma_\alpha}{ds} = b_\alpha \beta_\alpha s^{b_\alpha - 1} \qquad 10^3 m \leq s \leq 10^5 m \quad , \tag{61}$$

Note that at $s = 0$, STRAN sets $\sigma_y = 0$ and $\sigma_z = 0$.

The integral formulas for σ_y and σ_z given by Hoffer for travel distances greater than 100 km are

$$\sigma_y(t) = 0.5t \quad ; \quad t \text{ in sec} \quad , \quad \sigma_y \text{ in m} \tag{62}$$

$$\sigma_z(t) = (3K_z t)^{1/2} \quad , \quad K_z = 5 \text{ m}^2 \text{ sec}^{-1} \tag{63}$$

The derivatives used in computation when s is greater than 10^5 m are

$$\frac{d\sigma_y}{ds} = 0.5 \quad , \tag{64}$$

$$\frac{d\sigma_z}{dt} = 1/2(3K_z)^{1/2} t^{-1/2} \quad , \tag{65}$$

SECTION III

USER'S GUIDE

A. INTRODUCTION

1. General Data Processing Requirements

The data processing requirements for the STRAH system include the operation of two computer programs: Random-to-Grid and STRAH. The input to the STRAH program contains gridded data for wind components generated by the Random-to-Grid program. Because the STRAH program incorporates the map factor for the NMC grid (see Section II.B.1), the gridded wind data must be defined at the points of a rectangular subset or some integral subdivision of this grid. This grid is called the advection grid. An example of how the gridded wind component data may be prepared from randomly spaced station data using the Random-to-Grid program is discussed in Section III.B.

The program is designed to accept from cards at evenly spaced intervals DTIME new values of stability, mixing height, and source strength for each chemical component. The program is equipped with one option that reduces the requirement for stability and mixing height data to one 24-hour cycle and another option that reduces the source strength requirement to one set of constant values. Details are given in Section III.C.4.

The STRAH output data tape is discussed in Section III.C.5.

2. STRAH System Flow Chart

The STRAH system flow chart is given in Figure 7.

B. RANDOM-TO-GRID

1. Description, Function, Constraints

The function of this program is to use upper air multi-level wind speed and direction observations from a randomly distributed network of reporting stations to compute gridded fields of the average u- and v-component winds in a layer of a specified thickness and height above the ground.

The major inputs to the program are station wind direction and speed data from rawinsonde observations. These data are on magnetic tapes written at the Air Resources Laboratories in Silver Springs, Maryland. The output consists of a series of u- and v-component wind fields at 3-hour intervals. These data are written to tape in a form which may then be used by the STRAH program.

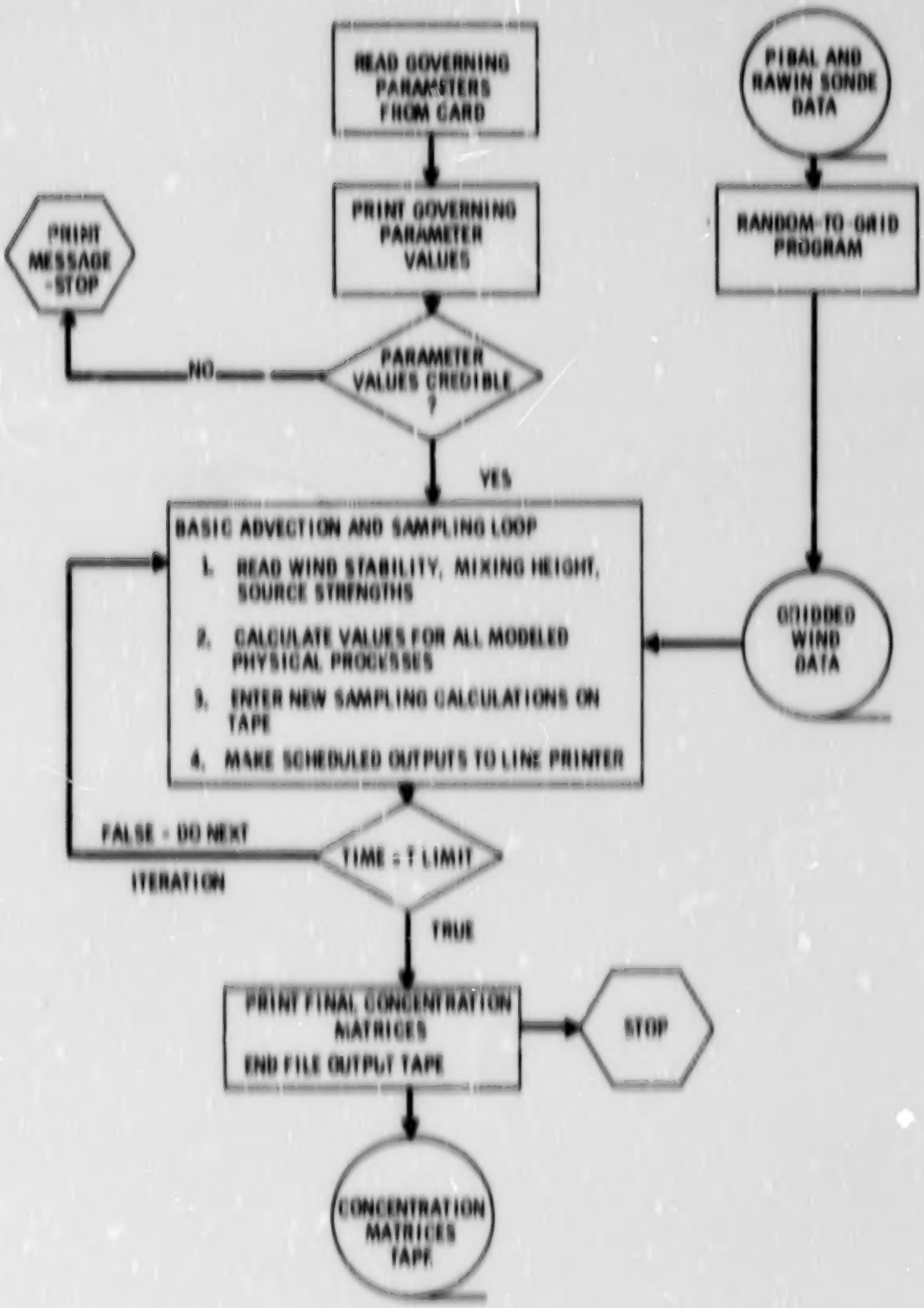

READ GOVERNING PARAMETERS FROM CARD
PIBAL AND RAWIN SONDE DATA
PRINT GOVERNING PARAMETER VALUES
RANDOM-TO-GRID PROGRAM
PRINT MESSAGE - STOP
NO
PARAMETER VALUES CREDIBLE ?
YES
BASIC ADVECTION AND SAMPLING LOOP
1. READ WIND STABILITY, MIXING HEIGHT, SOURCE STRENGTHS
2. CALCULATE VALUES FOR ALL MODELED PHYSICAL PROCESSES
3. ENTER NEW SAMPLING CALCULATIONS ON TAPE
4. MAKE SCHEDULED OUTPUTS TO LINE PRINTER
GRIDDED WIND DATA
FALSE - DO NEXT ITERATION
TIME = T LIMIT
TRUE
PRINT FINAL CONCENTRATION MATRICES
END FILE OUTPUT TAPE
STOP
CONCENTRATION MATRICES TAPE

Figure 7. System Flow Chart

The program consists of a main program and four subroutines, plus six subroutines which are used in transmittal of information from the data tapes.

The computation of the gridded wind fields takes place in the main program. In calculating the values at each point, the values at stations nearest the grid point are averaged, weighing the station values according to the reciprocal of the square of the distance between each station and the grid point. To avoid having to search for the nearest stations and calculate their distances from each grid point for every observation time, this operation is performed only once, at the beginning of the program. This requires that the latitudes, longitudes, and identification numbers of all stations which may be used later in the program must be input on cards (see input cards No. 6, 7, 8, and 9 in Section III.B.4, "Input Description and Formats") before entering the wind field calculation loop (see the second and third boxes in the "Flow Diagram - Major Functions," Section III.B.2).

The following subroutines perform specific functions in the program.

FASCND orders the elements of a vector according to their magnitude from the least to the greatest. FASCND is called in the section of the main program which orders stations according to their distances from each grid point.

MAPTIME is used to advance the given time by a specified interval in hours, in order to select data from the desired observation times, and skip information from other times.

RESCN2 reads rawinsonde and pibal station data from a specified file on the input tape.* It uses LYRWND to compute the average wind for the specified layer at each station. It returns to the main program u- and v-component layer averages for all available stations at a given observation time.

Six subroutines are employed to read the 32-bit word data on the input tapes, and convert to 36-bit Univac words. These subroutines, READ1, READ2, READ3, BUMP, NEXT, and SPLIT, are discussed in "Input Description and Formats," Section III.B.4.

3. Flow Diagram - Major Functions

The execution sequence of the major operations performed in RWGRD is schematically represented in Figure 3.

*RESCN2 searches for the desired observation time on the input tape. The tape must be prepositioned however, using appropriate job control language (see Section III.B.3) before the execution of the program.

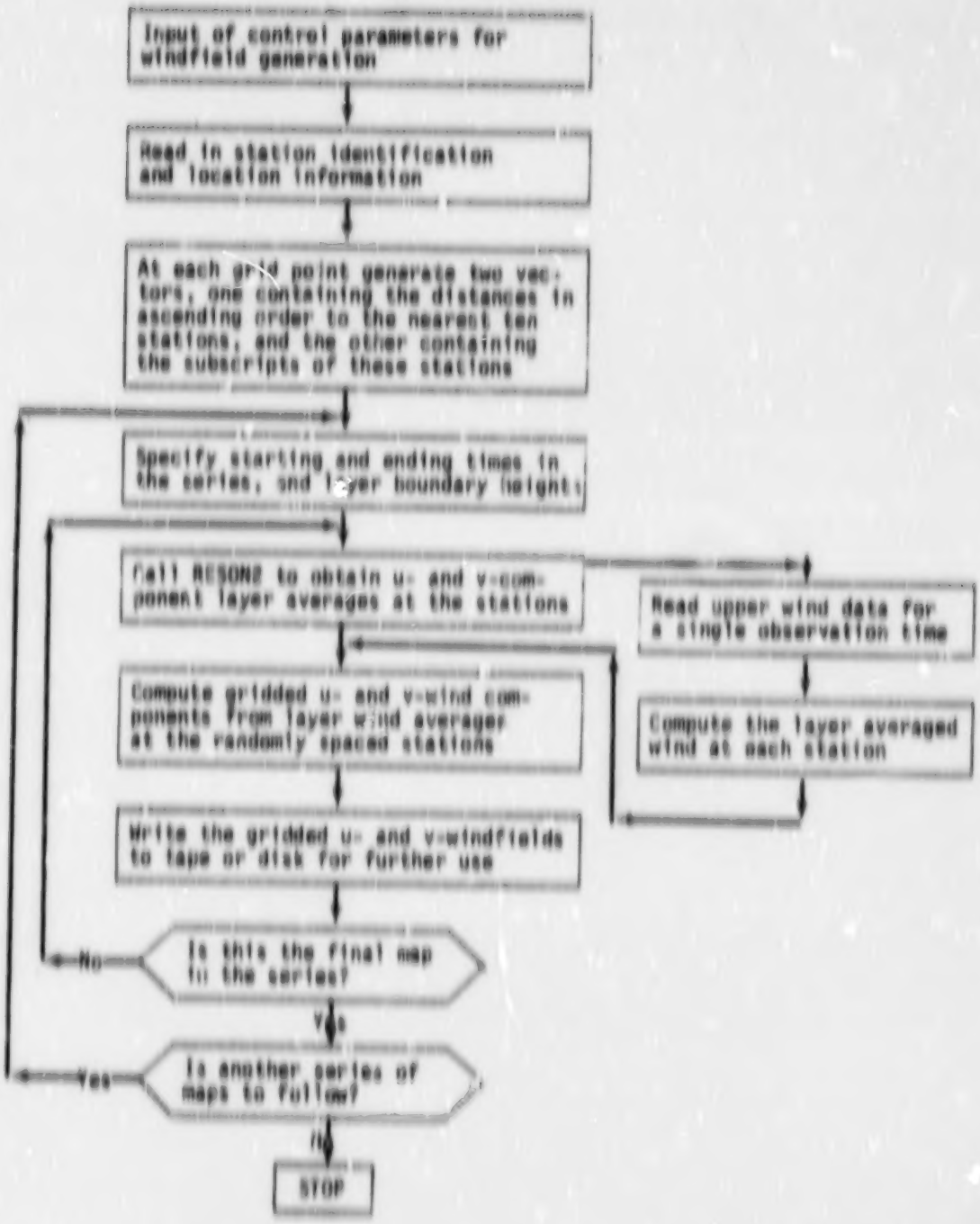

Input of control parameters for windfield generation
Read in station identification and location information
At each grid point generate two vectors, one containing the distances in ascending order to the nearest ten stations, and the other containing the subscripts of these stations
Specify starting and ending times in the series, and layer boundary heights
Call RESOND to obtain u- and v-component layer averages at the stations
Read upper wind data for a single observation time
Compute gridded u- and v-wind components from layer wind averages at the randomly spaced stations
Compute the layer averaged wind at each station
Write the gridded u- and v-windfields to tape or disk for further use
No
Is this the final map in the series?
Yes
Yes
Is another series of maps to follow?
No
STOP

Figure 8. Random-to-Grid Flow Diagram - Major Functions

3. Executive Control Language and Deck Setup

The following set of control cards is required to execute the Random-to-Grid program on the UNIVAC 1110.

RNGRD

EXECUTIVE CONTROL LANGUAGE(ECL)

@RUN,PRI/OPTS RUNID/CORE/TAPE/DISC,ACCT,PROJ/CLASS,RUNTIME,PAGES/CARDS,STIME

@ASG,T QUAL*WINDTAPE.,16N,999999 (ASSIGN HEFTER WIND TAPE)

@USE 10,QUAL*WINDTAPE. (ACCESS HEFTER FILE ON FORTRAN UNIT 10)

@MOVE QUAL*WINDTAPE.,N (POSITION HEFTER TAPE TO FIRST DESIRED FILE, EACH FILE HAS 1/2 MONTHS DATA, MOVE HEFTER FILE N NUMBER OF FILES)

@ASG,T/W QUAL*RNGRDTAPE.,16N,888888 (ASSIGN RNGRD OUTPUT TAPE)

@USE 5,QUAL*RNGRDTAPE. (WRITE RNGRD TAPE ON FORTRAN UNIT 5)

@ASG,A QUAL*PROGFILE. (ASSIGN RNGRD PROGRAM FILE)

@XQT QUAL*PROGFILE.RNGRDPGM (EXECUTE RNGRD ABSOLUTE PROGRAM)

(INSERT THE DESIRED RNGRD CONTROL CARDS HERE)

@FIN
@@
@@

NOTE: ALL UNDERLINED PARAMETERS TO BE SUPPLIED BY THE USER, RUN CARD PARAMETERS, QUALIFIERS, FILE NAMES, REEL NUMBERS AND RNGRD CONTROL CARD DATA.

4. Input Description and Formats

Card input to the RMCRD program is detailed in Table 5.

TABLE 5. CARD INPUT DESCRIPTION

Card No.	Columns	Format	Name	Definition
1	1-64	16A4	ITLE	Title of calculation run
2	1-5	I5	NP	Number of stations for which data may be available
2	6-10	I5	NSX	Starting x-direction grid point value. x=0 for NSX=1
2	11-15	I5	NSY	Starting y-direction grid point value. y=0 for NSY=1
2	16-20	I5	NFX	Final x-direction grid point value
2	21-25	I5	NFY	Final y-direction grid point value
2	26-30	I5	KTAPE	Write wind fields to tape: 1=yes, 0=no
2	31-35	I5	NSTL	Minimum number of stations to be used in any grid point calculation
2	36-40	I5	INT	Print interval, print out one of every "INT" u- and v- fields. If INT=0, no fields will be printed
3	1-80	16I5	KSX(I), I=1,NFY	For variable left boundary. Specifies the lowest x-value in each row, from 1 to NFY
4	1-80	16I5	NFX(I), I=1,NFY	For variable right boundary. Specifies the lowest x-value in each row, from 1 to NFY
5	1-10	F10.0	RCH	Radius in grid units within which all stations are to be used in an interpolation for a given point
6	11-20	F10.0	XMMC	With respect to the octagonal 47 x 47 MMC grid (see Figure 9) the x-value of grid point (1,1) on the interpolation grid
6	21-30	F10.0	YMMC	With respect to the octagonal 47 x 47 MMC grid (see Figure 9) the y-value of grid point (1,1) on the interpolation grid

TABLE 5 (continued). CARD INPUT DESCRIPTIONS

Card No.	Columns	Format	Name	Definition
5	31-40	F10.0	RFC	Resolution factor. The ratio of the interpolation grid spacing to the NMC grid spacing. RFC=1.0 yields grid with the resolution of the NMC grid (Δs ≈380 km at 60°N)
5	41-50	F10.0	THET	Number of degree of clockwise rotation of the x-axis on the interpolation grid from the x-axis on the NMC grid
6*	1-80	16I5	KSTA(I), I=1,NP	Last four digits of each station number for stations whose observations might be used
7*	1-80	16F5.2	X(I), I=1,NP	Latitudes of stations whose observations might be used
8*	1-80	16F5.2	Y(I), I=1,NP	Longitude of stations whose observations might be used
9*	1-80	16(1X, A4)	NAMSI(I), I=1,NP	Names or abbreviations of stations whose observations might be used
10	1-48	12A4	KMON(I), I=1,12	Three letter abbreviations for the months of the year
11	1-5	I5	IYS	Last two digits in starting year of the series
11	6-10	I5	MS	Starting month of the series
11	11-15	I5	IDS	Starting day of the series
11	16-20	I5	IHS	Starting hour of the observation series
11	21-25	I5	IYL	Year of the last observation time in the series
11	26-30	I5	ML	Month of the last observation time in the series
11	31-35	I5	IDL	Day of the last observation time in the series
11	36-40	I5	IHL	Hour of the last observation time in the series
11	41-45	I5	KOTHR	Perform random-to-grid for another series of maps after this one: 1=yes; 0=no

*There might be more than one card necessary to read in this array.

TABLE 5 (continued). CARD INPUT DESCRIPTIONS

Card No.	Columns	Format	Name	Definition
11	46-50	I5	FREW	Rewind input tape before starting this series: 1 = yes, 0 = no
12	1-5	F5.0	SB	Height above ground of the bottom of the desired layer
12	6-10	F5.0	ST	Height above ground of the top of the desired layer
13	1-10	F10.1	FLATMN	Minimum latitude of station search area
13	11-20	F10.1	FLATMX	Maximum latitude of station search area
13	21-30	F10.1	FLONMN	Minimum longitude of station search area
13	31-40	F10.1	FLONMX	Maximum longitude of station search area
13	41-45	I5	IDT	Selected map interval for analysis. IDT is an integer multiple of the smallest time interval (in hours) between observed data, and less than or equal to 24 hours

---

Magnetic tape input to the RHORD program consists of pibal and rawinsonde data which has been reduced from ETAC Upper Air data tapes by the NOAA Air Resources Laboratories and converted for use on EPA's Univac 1110 computer. The data are in 80-column card-image format.

Each month's data are divided into two files on the tape, the first covering days 1-15, and the second covering days 16 through the end of the month. Data for each observation time are headed by a descriptor record (record type #1 in Table 6) containing the date and time, number of reporting stations, and number of records to be skipped to get to the next observation time. Data are reported four times daily (0000, 0600, 1200, and 1800 GMT). Because of the relatively sparse data coverage at 0600 and 1800, RHORD uses only the 0000 and 1200 GMT observations.

Within each observation time, data are grouped according to station number, and each station's data are organized in ascending order by level of observation. Data for each station are headed by a descriptor record (record type #2 in Table 6), giving the station number, latitude and longitude (in degrees and hundredths of degrees), station elevation (in meters), elevation of the surrounding terrain (in meters, averaged over a 1° by 1° square), and the number of observation levels reported for the station.

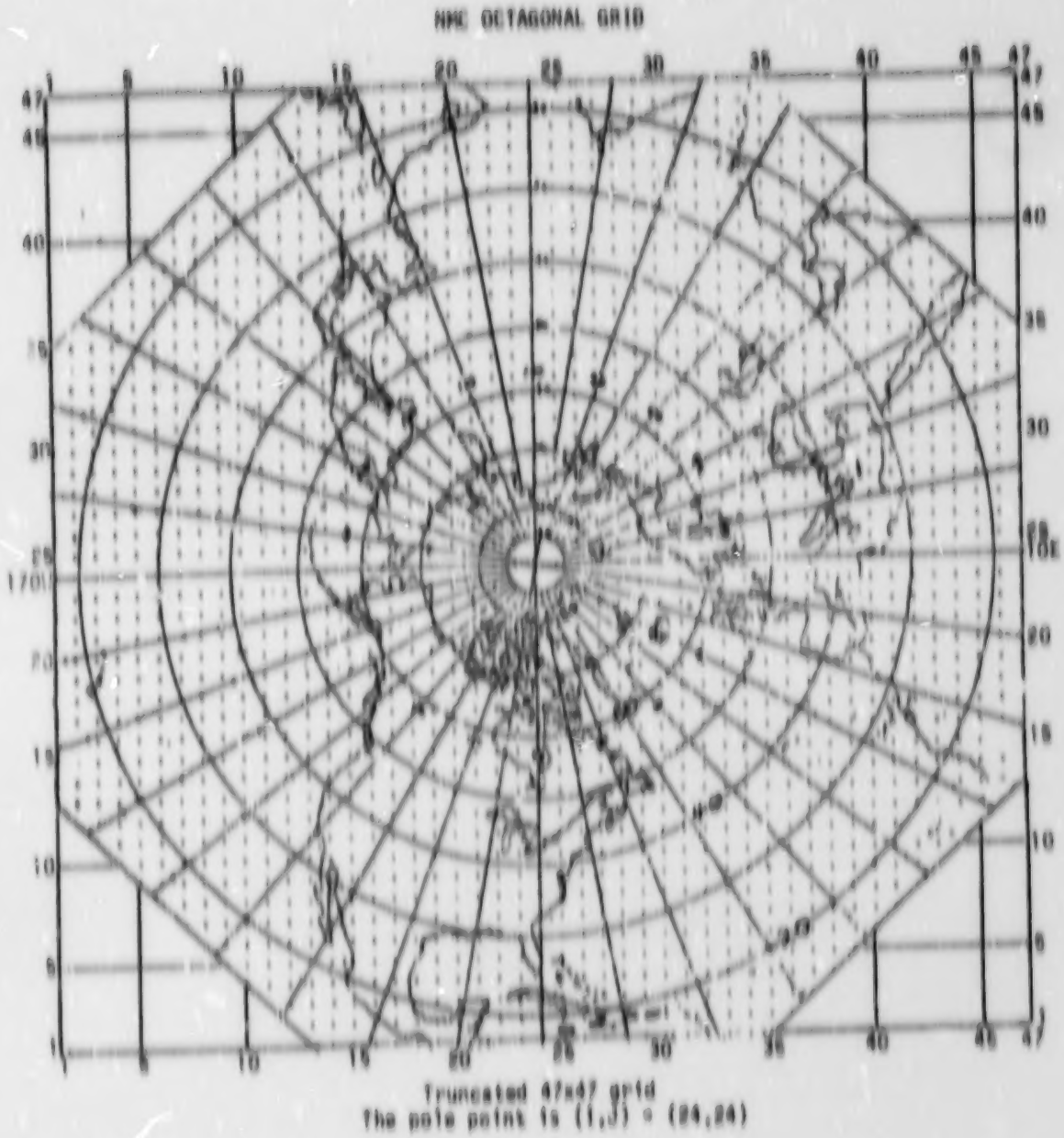


Figure 9. Truncated NMC grid, used as a basis for interpolation grid positioning specified on input card #5 to RMOBD

The data for each observation level resides on a single logical record (record type #3 in Table 6), and includes the height of observation (in meters), wind direction (in degrees), and wind speed (in meters per second).

TABLE 6. WIND DATA TAPE INPUT DESCRIPTION

Record Type	Character No. (column)	Format	Name	Definition
#1	1-3	A3	IM	Month of observation
#1	4-7	I4	J3	Year of observation
#1	8-9	I2	J4	Day of observation
#1	10-11	I2	J5	Hour of observation (GMT)
#1	12-15	I4	NS	Number of stations reported for this observation time
#1	16-20	I5	NREC	Number of records to skip to reach next observation time
#2	1-5	I5	ISTAT	Station number
#2	6-10	F5.2	FLAT	Latitude (degrees and decimal fraction)
#2	11-17	F7.2	FLON	Longitude (degrees and decimal fraction)
#2	18-22	F5.0	SHT	Station height (meters)
#2	23-27	F5.0	HTS	Terrain height (meters)
#2	28-29	I2	NLP	Number of observation levels
#3	1-5	F5.0	HS	Observation height (meters)
#3	6-8	F3.0	DIR	Wind direction (degrees)
#3	9-12	F4.1	SPD	Wind speed (meters per second)

The data on these tapes were written in the 32-bit word configuration of the IBM equipment used by ARL. As such, they must be converted to the 36-bit word Univac configuration. This is accomplished in RNORD by use of the six input and conversion subroutines, READ1, READ2, READ3, NEXT, SPLIT, and BUMP.

Call statements in RESON2 to the first three of these subroutines correspond to and perform the tasks of Fortran READ statements which would read and return data from record types #1, #2, and #3 described above.

Subroutine HEMT is called by the three READ subroutines to obtain information from the tape. Subroutines SPLIT and BUMP are used by the READ subroutines to rearrange the IBM bit structure into the Univac configuration.

5. Output Description and Formats

There are two forms of output from this program. The most important of these is the tape output. This contains gridded u- and v-component wind fields appropriate for use with the ATRAM program. The second form is the printed output which gives some of the input information, and, if desired, station layer-averaged u- and v-component winds followed by gridded u- and v-component wind field values at each observation time.

Tape Output. Information is written to a tape or disk using the three unformatted binary write statements below.

```
WRITE(3) IYR, MON, IDA, IHR, SB, ST, NSX, NFX, NSY, NFY
WRITE(3) ((UG(I,J), I=NSX,NFX), J=NSY,NFY)
WRITE(3) ((VG(I,J), I=NSX,NFX), J=NSY,NFY)
```

The first statement writes the year (last two digits), month (integer), day, and hour of the observation time, the height in meters above ground of the bottom, and of the top of the averaging layer, the starting and final x-coordinates, and the starting and final y-coordinates on the wind field grid. The second statement writes the entire gridded u-component array, and the third writes the entire gridded v-component array.

This sequence is repeated at each of the observation times for which wind field data is computed. There are no end-of-file markers between records or observation times.

Printed Output. The printed output may be divided into two types, standard and optional. The standard output is always present. The presence of the optional output depends on the value of the input control parameter IMT (see "Input Description and Formats," card number 3).

Standard output includes the following:

- Page 1: listing of station numbers, latitudes, and longitudes which were read from input cards.

- Page 2: title of calculation run; station names; x-coordinates of stations; y-coordinates of stations; starting and final x-grid coordinates for each u; the height above ground of the bottom and the top of the averaging layer; and the minimum and maximum latitudes and longitudes of the station search area.

The optional output applies to information from each observation time. This information is printed out once in every "INT" observation time. If INT=0, no optional information is printed. For each observation time for which data are to be printed, the following information is included in the output:

- Page 1 (Optional Printout): heading containing time of observation and boundaries of the layer; a table giving station number, latitude, longitude, station elevation, and the layer-averaged u- and v-component winds, for each station for which data were read from the tape.

- Page 2 (Optional Printout): u- and v-component station layer winds, printed to check their transfer from RESON2 into the main program; the number of stations used in the interpolation for each grid point,* gridded layer u-components (for the observation time, and the gridded layer v-components* for the observation time.

6. Diagnostic Messages

Subroutine RAFOM2. If there is no observational data available on the source tape for the designated time, the following message will be printed, with the number of the month designated by mm, the day by dd, the year by yy, and the hour by hh:

"RECORD NOT AVAILABLE FOR mm/dd/yy, hhZ"

Subroutine LYRWND. There are two diagnostic messages which may appear in the listing of layer-averaged u- and v-component winds (see Section III.B.5, "Page 1 (Optional Printout)"). Since no winds can be interpolated for a layer which lies entirely below, or entirely above all of the wind observations, no layer averages are calculated in such cases. The diagnostics associated with this situation are:

" - ALL OBSERVATION BELOW LAYER," and "ALL OBSERVATION ABOVE LAYER."

C. STRAH PROGRAM

1. Description, Functions, and Constraints

The purpose of this program is to model the distribution of ground-level concentrations over a rectangular area approximately 1000 km on each side resulting from emission of multicomponent plumes from several elevated sources within the area. Broadly, the program can be divided into three functions--a trajectory function, a dispersion function, and a sampling function.

*The values appear in the printout as they would appear on the grid, i.e., with the value in the lower left corner corresponding to the lower left grid point.

The executive control and trajectory function are in the main program. The main program reads in all input parameters, prints these out, defines the advection and sampling grids on the 47 by 47 NMC grid, calls the major subroutines, computes plume trajectories, and governs all output, of which there are two kinds, line printer and magnetic tape.

The input and output parameters are described in detail in III.C.4 and III.C.5, respectively. The basic equations used are given in Section II. Therefore, this section will be primarily of a descriptive nature, explaining how these things are used, how the program functions, and what constraints the user must be aware of.

a. Grid Definition and Spacing

There are three grids to be considered by the user, the 47 by 47 NMC grid, the advection grid, and the sampling grid. Average concentrations are computed for all intersections of the sampling grid (as well as for up to ten particularly specified other locations within the sampling grid), which is a rectangular area within (or equal to) the advection grid.

Each of the three grids has its own coordinate system. The definitions of these and the relationships among them are described in II.B.1.

The reasons for providing the capability to make the sampling grid smaller than the advection grid involve both dispersion physics and computer logistics. The number of intersections that can feasibly be specified for the sampling grid are limited primarily by computer core size in view of all the other core requirements in the code. The spacing between consecutive intersections is limited by the fact that if the spacing is too large, much of the concentrations from the plumes will go undetected. Therefore, it may be necessary to settle for a sampling grid that covers only part of the advection grid. Also, in this way, contributions from sources outside the sampling grid may be considered. The present dimensions of the code allow for a sampling grid of not more than 11 by 11 equally spaced intersections.

The location and subdivision of the sampling grid are defined by the input parameters specifying the locations on the advection grid of the lower left and upper right corners of the sampling grid, along with the ratio of the scale of the sampling grid to that of the advection grid (see III.C.4). The specifications can be any positive floating point numbers subject to the constraints of dimensions of the sampling and advection grids.

The advection grid is limited to an array of not more than 17 intersections in the horizontal direction of the NMC grid and not more than 13 intersections in the vertical direction. The location and subdivision of the advection grid are defined by integer input parameters specifying the locations on the NMC grid of the lower left and upper right corners of the advection grid, along with the scale ratio of the advection grid to the

NMC grid (see III.C.4). Since these are all integer specifications, the boundaries of the advection grid (also called the rectangle) are along lines connecting the intersections of the NMC grid, and all intersections of the NMC grid within and on the boundaries of the advection grid are also intersections on the advection grid. However, the total grid within the rectangle may be a finer grid than the NMC grid, formed by integral subdivision. That is, the spacing on the advection grid may be two or three times as dense as that on the NMC grid.

Usually the spacing of the intersections on the advection grid is either identical to that of the NMC grid or twice as dense. In the first case, IDIV is 1; in the second, IDIV is 2. The choice depends on the spacing of gridded wind observations provided. If gridded winds are created especially for the NMC grid, IDIV must be 1. The NMC wind tapes available through the National Center for Atmospheric Research (NCAR) are examples.

But this spacing is approximately 350 km over the United States, and is hardly optimum on a grid that is approximately 1000 km on a side. If the user can make his own gridded wind tapes using synoptic weather station data over some portion of the United States for input data to a random-to-grid type program, he may conclude from inspection of a map of these stations that a denser grid would reflect the detail of the wind field more fully. Using this type of data, our choice for spacing in the advection grid is to double the grid density, i.e., to make IDIV equal to 2. This gives an average distance of about 175 km between successive grid intersections over the United States.

An estimate of the grid spacing on the sample grid can be made by considering the effective width of a Gaussian plume, which we will consider to be $6\sigma_y$. For a plume increment that has traveled 200 km, this figure would be about 50 km. Therefore, grid spacing on the sampling grid of this order would be appropriate. For example, if DIV is 4.0, the grid spacing on the sampling grid is one-fourth that on the advection grid, and a typical grid spacing on the sampling grid would be about 45 km (if IDIV is 3).

b. Other Initial Functions

After the grids have been defined and all input parameters have been read in, there is a printout of the essential information (see III.C.5). Next, certain of the input parameter values are checked for acceptability. If an unacceptable value is found, it is printed out and the run is stopped (see III.C.6).

If the run survives the diagnostic check, the next computations are of map factors for the intersection points of the advection grid (see IV.B.1). These factors are necessary because the scale on the NMC grid is a function of latitude, and the basic grid spacing holds only at 60°N. The next step consists of computing the latitudes and longitudes of all sampling grid intersections and printing these out.

The last step before beginning the major loop, the advection loop, is to initialise appropriate values. The average concentration matrices CHISAV and CHIIAV are zeroed out since their values are computed by summation with the same matrix element on both sides of the equal sign in the Fortran statement. The matrices containing σ_y and σ_z for each plume element, SIGMY and SIGMZ are zeroed out for the same reason. The variable TIME, which is incremented once in each iteration of the advection loop by

$$TIME = TIME + DTIME ,$$

is also set to zero. This variable gives the current running time in hours at any time during the run. The variable TMAP, which is incremented also, once, during each iteration of the advection loop

$$TMAP = TMAP + DTIME$$

is also set at zero. TMAP is used to call in new gridded wind maps at the appropriate times. Since the interval between maps is DMAP hours, (see III.C.4), TMAP is allowed to increase until it equals DMAP, at which time a new map for each of U and V, the wind components in the horizontal and vertical directions, respectively (on the NMC map), is read in. At this time, TMAP is reset at zero.

Also, the vector NINCV containing the number of increments in each of the NSOURC plumes, is initialised at 1. This is because there is just one plume increment to be advected from each source as the run begins. Each element of the vector is incremented by 1 at the end of each major iteration, thus keeping track of the total number of increments in each plume.

c. Beginning the Major Loop

With all these values initialised, the major iterations are ready to begin. The first time through, two sets of wind maps are read in. The first set consists of maps for U and V at the initial time of the run, and the second set is for U and V DMAP hours later than the initial time. These two sets of wind maps are used for the bilinear interpolation in time and space (see II.B.3) that is used to calculate the wind for any point on the grid at any time between two map times. The fraction TMAP/DMAP is used to calculate the time interpolation. On subsequent iterations, if TMAP is less than DMAP, the wind map reading part is skipped. When TMAP is not less than DMAP, the last of the two sets of wind maps in core is transferred to the core locations of the first set of maps and a new second set is read in.

Following the wind map section, a Subroutine KALEND is called that computes the hour (0 to 23), the day, the month, and the year, effective at the end of the current major iteration. Next, the time interpolation values, with respect to wind maps CA and CB, are calculated. Then the

matrices CHI and CH, the average concentrations over the interval DTIME for both the gridded and particular sampling locations are set at background levels.

The stability, mixing heights and source strengths are read in as functions of time according to two options available to the user, see III.C.4.

d. The Advection Routine

The advection process is accomplished by three nested Do loops. The outer one is for sources, the next is for increments from each source, and the inner one consists of two steps to carry out the two-part iteration for each advection step described in II.B.3.

The X and Y positions on the advection grid of the plume increments are kept track of in the matrices XP(K,MP) and YP(K,MP), respectively, where the first index is for source and the second for increment. The value of MP is in order of release from the source, i.e., MP = 1 for the first increment released. This increment will usually be the furthest from the source. As the run progresses from one major advection step to another, the individual plume increments retain their index values while the position values are altered by addition or subtraction, depending on the direction of the advection.

Within the two inner Do-loops, the advection calculations are made for each increment of each plume. The calculated values include the new X and Y positions of the increments on the advection grid, the average wind speed in cm sec^{-1} (UU(K,MP)) for each increment, and the total distance advanced in cm (DS(K,MP)) for each increment. The wind speed and travel distance matrices are entered later into Subroutine STRAC for use in diffusion computations.*

Just before the end of the loop for plume increments is completed a Subroutine PLMRIS is called that computes the effective stack height for the emission if OPTION = 1.

Immediately after the Do-loop for the increments has been completed for all increments, but still within the Do-loop for the sources, another Do-loop for the increments is called to ascertain whether or not any plume increments have wandered off the advection grid. If it is found that the ith increment is off the grid, this increment and all those emitted before the ith increment are removed from further consideration. Since this removes increments 1 through i, the data pertaining to the remaining increments, positions, wind speeds, sigma values, total distance and time traveled, are all reindexed with the data that was for increment i + n, now being for increment n.

*see addenda

e. Subroutine STRAC and INTGRT

Following the reindexing of the increment data, Subroutine STRAC is called to determine ground-level concentrations at positions relative to the plume centerline and source location. Subroutine STRAC fulfills this function by providing numerical approximations to the solutions of equations (5a), and utilizing the resulting Q_y values in conjunction with (3) and (3) to determine corresponding concentration values.

The subroutine call necessary to execute subroutine STRAC is given as follows:

```
CALL STRAC (N,SUBMIN,SUBMAX,FACTOR,MODE,
            TIME,OPTION,NCOMP).
```

The arguments of the call list are defined in the glossary of computer terms. Additional information is exchanged between the subroutine and the main program via the COMMON statement which reads as follows in the main program:

```
COMMON NINCV(10),CQ(6,100,10),CREG(6),DS(10,100),WU(10,100),H(10),
SIGMY(10,100),CORRD(7,100,6),ISTAB(10,100),HH(10,100),XP(10,100),V
P(10,100),AM(10,100),SIGMS(10,100),PTIME(10,100),XREG(10),YREG(10)
,VIRTH(10,100)
```

In the calling sequence given above N is the number of the particular source, and MODE dictates the calculation sequence in STRAC as indicated in the glossary. It should be noted that for computational efficiency MODE should be set as low as possible. Unnecessarily high values of MODE (e.g., MODE set equal to 4 and a nonreactive plume) will result in essentially the same output, but will direct STRAC to perform nonessential calculations. Setting OPTION to 1 or 2 dictates whether calculations in STRAC utilize the conventional Gaussian or limited mixing-height distributions. Under option 2 STRAC assumes that emissions are within the mixed layer at all times regardless of stack height.

SUBMIN and SUBMAX are minimum and maximum allowable downwind increment lengths for numerical integration in the x direction. Choice of these values is dictated by accuracy requirements, and also by the rates of plume transformation and removal. A reasonable rule of thumb is to try to maintain the increment lengths such that no more than 5% of the plume is transformed or removed in any given downwind step. With MODE = 1 (inert, nondepositing plume) no numerical integrations are performed, and thus downwind increment lengths will be as large as allowed by plume drift during the current time step. Under this condition, no values for SUBMIN and SUBMAX are required.

Since proportionately more transformation often occurs early in a plume's history, it is desirable to relax the downwind grid spacing requirement with increasing distance. This is accomplished by FACTOR, which allows the x grid spacing to be expanded for each successive increment as follows:

$$\Delta x\Big|_{\text{step } n+1} = \Delta x\Big|_{\text{step } n} * \text{FACTOR} \qquad (66)$$

STRAC limits expansion by Equation (66) to Δx intervals less than or equal to SUBMAX.

The remainder of the input variables are self-explanatory from Table 7. As noted above, much of the essential information is exchanged between STRAC and the main program via the COMMON statement. In particular, the computed ground-level concentrations

CGRND(I,H,K)

I = crosswind (y) position index

H = downwind increment index

K = component index,

as well as a crosswind spread parameter

SIGMY (H,M)

M = source index

are conveyed to the main program in this manner.

The layout of Subroutine STRAC is shown in Figure 10. Upon being called from the main program, this subroutine first initializes pertinent variables. Downwind distance and plume depletion factors, as well as the grid control variable TOTAL are set equal to zero. Following this the initial grid spacing in the x direction is set. If MODE equals 1, no numerical integrations are performed, and thus no grid subdivisions are required. The subroutine simply computes the concentrations at the given increment DS(H,M) and proceeds. If MODE does not equal 1, then the initial grid spacing is set to the value of SUBMIN or DS(H,M), whichever is smaller. x is then advanced one-half step, plume dispersion parameters are calculated, and values of the virtual source terms appropriate to that distance are obtained by adding the computed values for generation of material in the half-interval by reaction and deposition (taken to be zero for the first half-step). This completes the first step of the two-step Runge-Kutta integration.

Following this initial sequence, an integration over the full interval DX is performed. This is accomplished by calculating generation rates over the full interval using concentration estimates computed at the half interval on the basis of source terms calculated from step 1. Virtual source terms for that plume increment are then adjusted to reflect the gain of material during the distance step DX, arriving at a new set of terms QQP(K) = QQ(K,H,M) for each component. Various steps of this calculation are bypassed, according to the value of MODE.*

*See Addenda

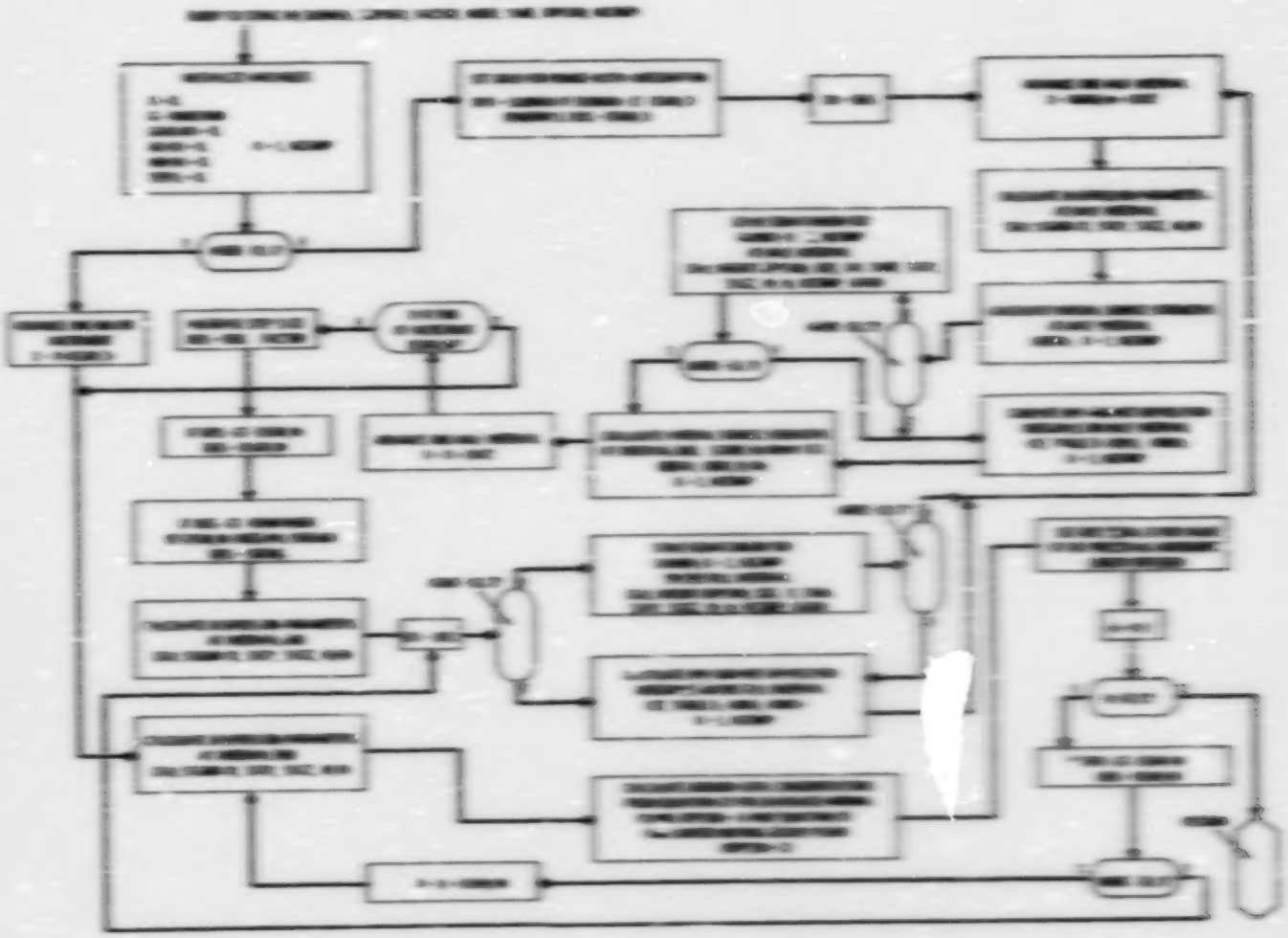


Figure 10. Flow Diagram for Subroutine SMC

Once the (QQ(K,N,M) K=1,NCOMP) array has been calculated at the full interval DX, ground-level concentrations may be computed. This, however, is performed only when the end of the DX interval happens to fall on the end of the major plume interval DS(M,N). If this is not the case, an additional downwind step is taken and the integration procedure repeats until this condition is satisfied. Under conditions when a major plume interval has been traversed, ground-level concentrations are calculated at seven points across the y-axis of the plume, starting at y=0 and proceeding to one side at intervals of $1/3\sigma_y$. Equation (2) or (3) is used for this purpose, depending upon whether a bivariate-normal (OPTION=1) or limited mixing-height (OPTION=2) model is being employed.

Regardless of whether or not a major plume interval is completed on a given step, a grid-space adjustment is always attempted before the next integration step is performed. If a major plume increment has been completed on the last interval, the next step size, DDS, is set equal to that of the preceding step (DDSOLD) or to that of the next major interval DS(M,N), whichever is smaller. If a major interval has not been completed on the current step, then DDS is set equal either to its current value times the grid expansion factor FACTOR, or to SUBMAX, whichever is smaller. Furthermore, if DDS exceeds the distance to the end of the major interval DS(M,N), then it is set equal to this distance. This provision guarantees that calculations ultimately will coincide with points at the ends of the major intervals.

Upon reaching the end point of a major interval and printing, the increment index N is reduced by 1, and computations for the next increment are initiated. N equal to zero signifies that calculations for the total plume have been completed; under this condition control is returned to the main program.

After an x grid-space adjustment has been made, the subroutine re-enters the first step of the two-step Runge-Kutta integration. In contrast to the initial entry which assumed all generation processes were negligible, each subsequent entry calculates values of the generation of material in the half-step. This is performed in the same manner as used previously for the full-step integration, calling Subroutine INTGNT to approximate equation (10) for the chemical reaction term, and using the formulae in Table 1 to calculate corresponding terms for dry-deposition and washout. Following calculation of the generation terms the subroutine advances the value of x one-half increment, adjusts the source terms as appropriate to the new half interval position and proceeds.

As indicated above, the STRAC subroutine calculates through NHNCV(J) major increments of plume, storing ground-level concentrations COND(I,N,K) (I=1,7; N=1, NHNCV(J), K=1,NCOMP) for subsequent use by the main program. Here, the index J denotes source. For any given time increment, STRAC must be called M times to compute concentrations of plumes from M different source locations.

Subroutine INTGRT. Subroutine INTGRT serves the important function of numerically approximating solutions to the double integral equation (5). It is interrogated by Subroutine STRAC by the call

CALL INTGRT (OPTION,QQK,UK,TIME,SIGV,SIGR,N,N,NCOMP),

where QQK is the array of current virtual source strengths and the remaining symbols have been defined previously. The primary variable returned to the calling program is the generation of material by chemical reaction GAIN(K), K=1,NCOMP, which is communicated via the blank common route.

Two major paths exist in INTGRT, corresponding to the bivariate-normal and limited mixing-height models; these are followed with OPTION set equal to 1 or 2, respectively. The paths are shown in the flow diagram in Figure 11, which, because of the involved nature of the subroutine, employs a somewhat more detailed method for portraying the nested loops. With OPTION=2, the program enters into a nested loop which starts by setting the first value of x where integration over y is to be performed. This is accomplished by choosing the first value of ξ_i shown in Table 3, and scaling according to equation (15) or (16). The program proceeds to the next loop which scales the y values along the path of integration in a similar manner. This is done sequentially, using equation (2) to calculate concentrations C(K) of the NCOMP components at the given (x,y) location, and then calculating the corresponding reaction rates by the subroutine call: CALL RATE (C,FUNCT,N,N,TIME). The two-dimensional array FUNCT returned by RATE corresponds to the reaction rate (moles/cm^3 sec) of each component at each y position at fixed x. When all of these values have been computed for a given x-position they are integrated over y (of equation (5)) sequentially for each component. This is accomplished in a DO loop, which indexes K, stores the values of FUNCT in a one-dimensional dummy array FUN, and then calls the Subroutine LAGURE, which performs the actual Gauss-Laguerre numerical integration of the function with base values FUN. The integrated values SINT are descaled according to equation (13) and stored in the array SI(1,K). This array is integrated by a second call of subroutine LAGURE, the results are descaled according to equation (16), and the desired values GAIN(K) are calculated.

In the event that limited mixing-height calculations are specified (OPTION=2) the subroutine performs integrations in a manner similar to that described above. The differences between these two paths are two-fold. First, the limited mixing-height equation (3) is utilized for OPTION=2, rather than its counterpart equation (2). Second, the numerical integration process is conducted in the y-direction only, since the assumed uniformity of concentration with height allows a formal integration to be performed in the x-direction.

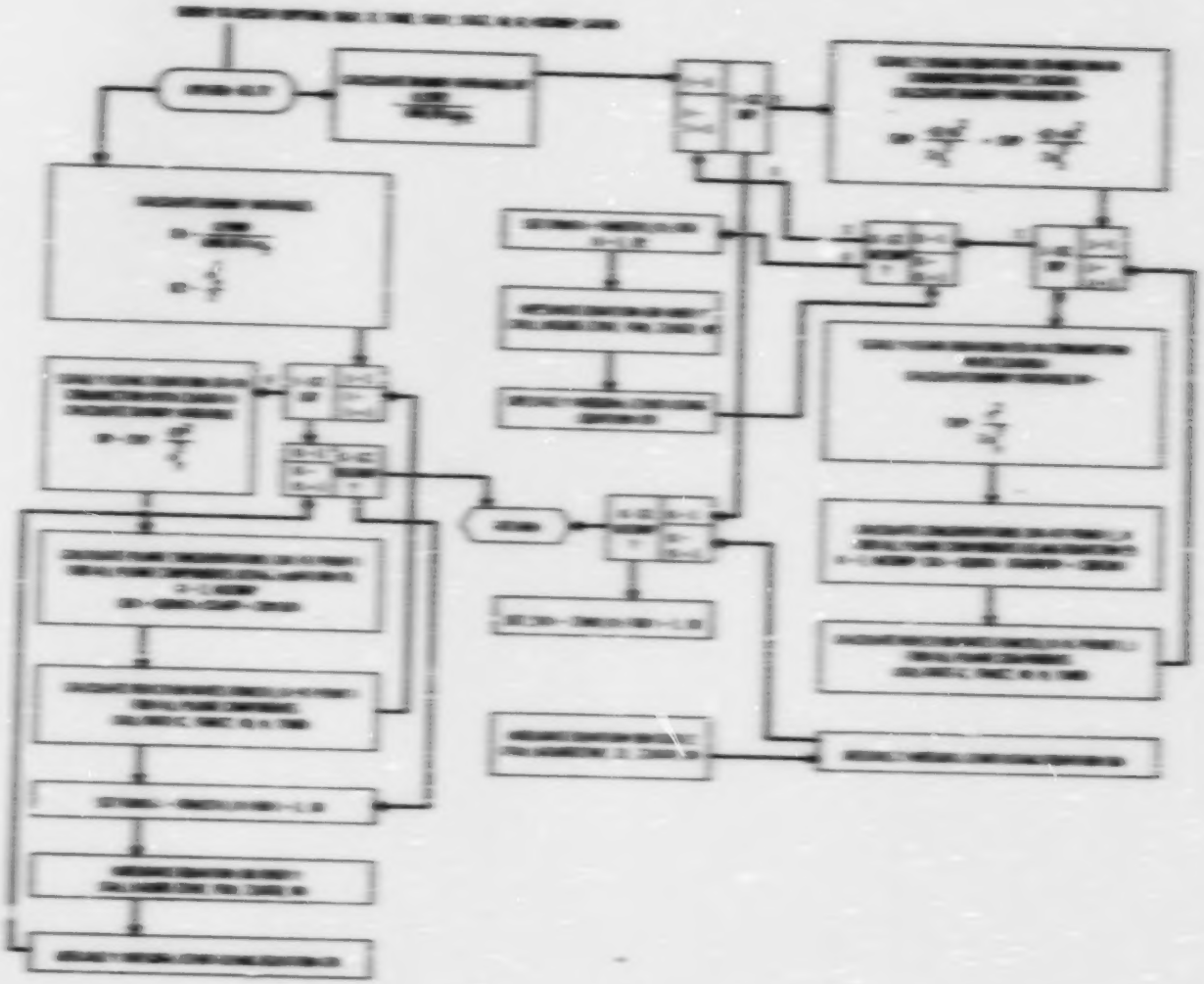


Figure 11. Flow diagram for [illegible]

f. Subroutines RATE, WSHOUT, and DRYDEP

The subroutines RATE, WSHOUT, and DRYDEP are written, in concordance with the discussion on pages 19 to 23, to return respective values of conversion rate, washout coefficient, and deposition velocity when interrogated by Subroutines STRAC and INTGRT. The three subroutines are considered to be modular, and are expected to be replaced as appropriate by the user for investigation of systems other than the example given here.

As indicated in equation (6) Subroutine RATE calculates the microscopic rate of chemical reaction at a given point in the plume where the concentrations are denoted by the vector C(K). One call of the subroutine results in generation of reaction rates for all components in the system, which are denoted by FUNCT (J,K). Here K is the component index and J pertains to crosswind location of the point of current calculation.

The subroutine RATE shown in Table 3, as discussed previously, is limited to two components (ostensibly SO_2 and sulfate). Their conversion rates are assumed to be first order in SO_2 concentration, and have the rate constant

$$k = 5.56 \times 10^{-6} \text{ sec}^{-1}$$

as indicated in Table 3. Thus the conversion rate for SO_2 (K=1) is given by

$$\text{FUNCT}(J,1) = -5.56 E-6 * C(1) ,$$

Since decay of SO_2 results in formation of sulfate (K=2), the corresponding conversion rate for sulfate is

$$\text{FUNCT}(J,2) = - \text{FUNCT}(J,1) ,$$

One should note that modification of this subroutine to include more complex reaction phenomena is trivial. For example, a reaction whose decay is second order with respect to its own concentration, first order in component 2, and whose generation is 3/2 order in component 1 can be expressed readily by the form

$$\text{FUNCT}(J,1) = k_1 * C(1)^{**2} + k_2 * C(2) - k_3 * (C(3)^{**1.5} ,$$

Subroutine WSHOUT operates in a manner similar to RATE, in that it produces washout coefficients (sec^{-1}) for each of the plume components when interrogated by the calling subroutine. These coefficients are denoted by WOC(K),

where K is the species index. At present all values of WOC are set equal to zero, presuming a no-rain situation. Other values may be set by the user as desired; this option may include time-variant values of the washout coefficient, if rain intensity data are available as a function of time and location.

Subroutine DRYDEP provides deposition velocities (cm/sec) of each plume component, which may be time variant at the user's option. They are denoted by VD(K) where K is the component index. For the present case the deposition velocity for SO_2 is set equal to 1.0 cm/sec while that for sulfate assumes the value 0.1 cm/sec, in accordance with the previous discussion.

i. Subroutine SIGMA

Subroutine SIGMA computes values of σ_y and σ_z in cm and stores them in matrices SIGMY(M,N) and SIGMZ(M,N) respectively, where the index M is for sources and the index N is for plume increments. The computations are done in accordance with the equations in II.C.3.f.

As stated in this section, the σ values are computed as functions of travel distance out to 100 km and as functions of travel time thereafter. In both cases the σ values are added onto at each computation by computing a derivative at the current value of travel distance or travel time, multiplying the derivative by an interval of distance or time, and adding to the previous value. The derivatives with respect to travel distance are functions of stability, indicated by a variable KSTAB, which may take on values of 1,2,3,4,5,6. The initial values for σ are set in the main program as zero.

In order to compute the derivatives at the proper travel distance or travel time, the travel distance of each plume increment, XM(M,N) and the travel time of each plume increment PTIME(M,N) are kept track of in SIGMA.

If the user should try to modify the subroutine, some confusion may result from the fact that the spatial derivatives, DSYDX and DSZDX are computed from empirical equations 60 and 61, with coefficients from Table 4, are for travel distance in meters, while the final σ values are in cm. Thus XC, the current travel distance is computed from cm quantities X and DX by multiplying 0.01 to convert to m. However, the final σ values are rendered in cm by multiplying the derivative by DX, which is in cm.

h. Subroutine LAGURE

Subroutine LAGURE performs the finite difference approximation described by equation (11). Here ZLAGR(I) is the independent variable (ξ_i in equation (14)), ARRAY(I), is the dependent variable ($f(\xi_i)$), and W(I) is the weighting function (given in Table 3). VALUE is the integral, which is returned to the calling program upon successful execution of LAGURE.

4. Subroutine SAMPLE

After STRAC returns control to the main program and still within the source loop, the Subroutine SAMPLE is called to interpolate to the intersections of the sampling grid the concentrations calculated by STRAC for each increment of the plume. SAMPLE also has an option to interpolate the concentrations to particularly specified locations or the sampling grid. The situation facing SAMPLE is illustrated in Figure 12. Here a plume with six increments is shown. The segmented line extending from the source, out to the first increment of the plume, is the axis of each increment of the plume. The two external lines are at a distance of $3\sigma_y$ from the axis on either side. Each crossplume line is perpendicular to the sourceward plume axis segment. The dots along the crossplume lines indicate the distances from the plume axis (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0) σ_y at which the concentrations computed in STRAC apply. The seven positions referred to in the description of STRAC are the axis position and the six positions on one side. The concentrations at the six positions on the other side are found by reflection. Concentrations have been computed by STRAC for 13 positions (including reflection) on all the crossplume lines shown. The dots were left off the last two for clarity.

It will be noticed that six of the intersections of the sampling grid fall within the bounds of the plume, so defined. SAMPLE locates these points and computes applicable concentrations for each, using concentrations for two of the points on each of the two crossplume lines defining the four-sided polygon the intersections lie in. The concentrations assigned to the grid intersections are stored in a matrix CHI(KP,I,J), where KP refers to the particular chemical component, and I and J are the subscripts for the particular grid locations.

Positions P_1 and P_2 are positions of particular sampling stations at which concentrations are to be computed. SAMPLE locates point P_1 as farther than $3\sigma_y$ from the plume axis and assigns no contribution from this source. SAMPLE locates point P_2 as nearer the plume axis of the second increment than $3\sigma_y$ and computes a concentration for each chemical component using the same interpolation method that is used for the grid intersections. These concentrations are stored as CH(KP,L), where KP refers to the chemical component and L to the particular sampling location.

When SAMPLE returns control to the main program, the DO-loop for the sources has been completed for one source. During each major advection step the loop is traversed NSOURC times during which SAMPLE superimposes the contributions from plumes from different sources on the grid and at the particular sampling locations additively. Thus, the average concentration for each chemical component at each grid intersection over the interval DTIME that is conveyed to output is the sum of contributions from several sources. The same is true for each particular sampling site.

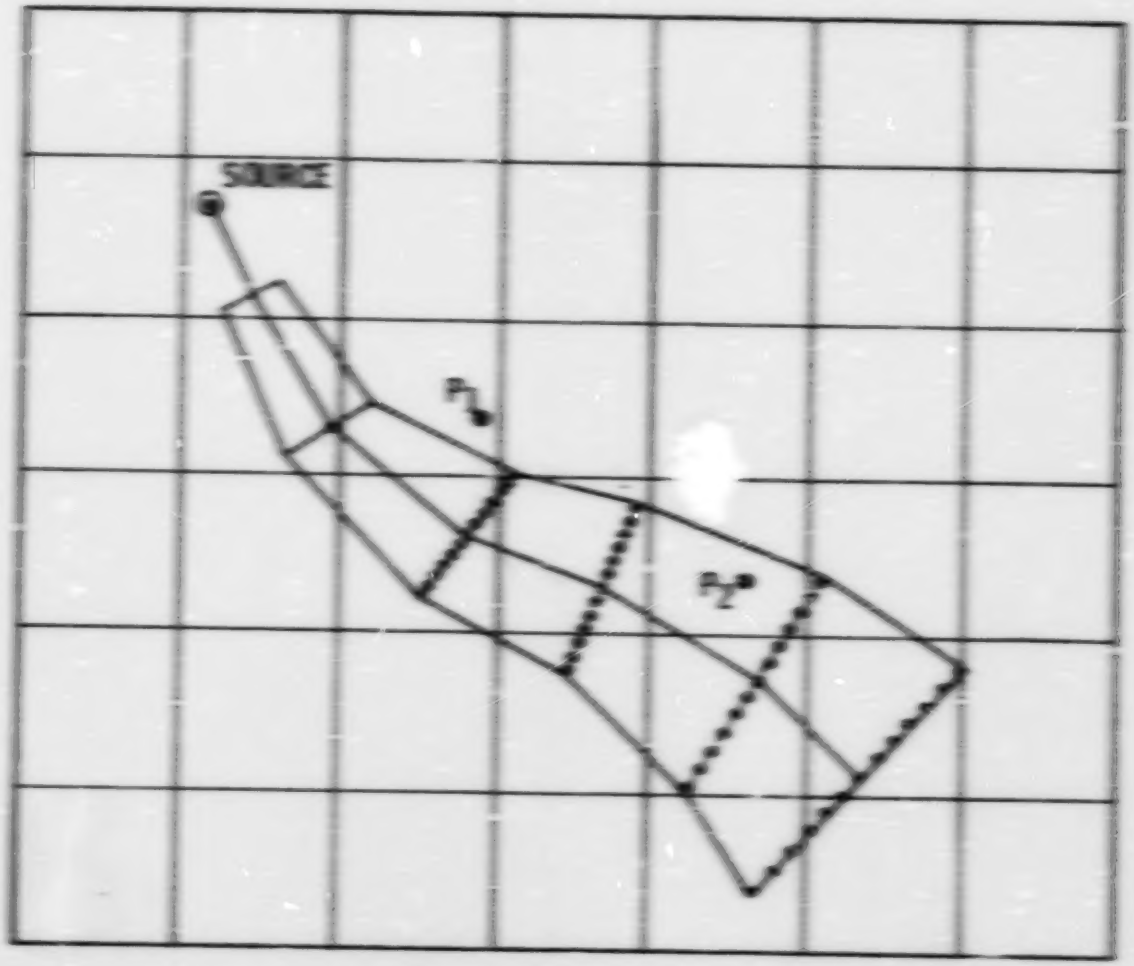


Figure 12. Schematic illustration of plane as seen in Schmucker (1970)

j. Completion of the Major Loop

After the source loop has been completed for all sources, contributions are made for each chemical component and for each grid intersection from the matrix CHI to the longer time averaging matrices CHISAV and CHILAV. The contributions are added as exposures, i.e., time integrated concentrations, by the statements

```
CHISAV(KP,I,J) = CHISAV(KP,I,J) + CHI(KP,I,J)*DTIME

CHILAV(KP,I,J) = CHILAV(KP,I,J) + CHI(KP,I,J)*DTIME   ,
```

where both matrices are calculated in mole-hr/cm^3, KP indicates the chemical component, I and J are the subscripts for the grid intersection location. As indicated in the discussion of program output (section III.C.5) CHISAV is averaged over some short period of time (DPRINT) such as 24 hours and is routinely printed out. Just before the print-out of CHISAV, the average concentrations are obtained in μgm/m^3 in Subroutine PRCHI by use of an appropriate factor with DPRINT the demominator.

Following the print-out CHISAV is zeroed out.

CHILAV is added onto, in the same way. At the end of the run, CHILAV is divided by the time for the entire run TLIMIT, and simultaneously converted to μgm/m^3.

Also, just before the printing of CHISAV, its elements are compared for storage in a maximum value array CHIMAX. The statement is

```
CHIMAX(KP,I,J) = AMAX1(CHIMAX(KP,I,J),CHISAV(KP,I,J))   .
```

Thus, CHIMAX stores the largest value from CHISAV for each chemical component at each grid intersection.

The concentration data, CH, for the particular sampling locations are averaged into longer periods in just the same way, using matrices called CHSAV and CHLAV. The maximum values over all matrices called CHSAV are stored in the matrix CHMAX.

Following these printing and storing steps, the number of increments in each plume is incremented by one in preparation for the next major iteration. The last statement in the major iteration loop checks the value of TIME against that of TLIMIT. If TIME is less than TLIMIT control skips back to the beginning of the major loop and starts the next iteration.

k. Termination of the Run

The program steps associated with the termination of the run are executed after TIME is checked against TLIMIT, if TIME is equal to or greater than TLIMIT. At this point all values on the matrices CHILAV, CHIMAX, CHLAV,

CHMAX are printed out. An end-of-file is written on the tape that has been accumulating print-out of the matrices CHI and CH at the interval DTIME.

The above-mentioned steps are also executed if the run is aborted either by encountering an end-of-file on the wind tape or by a plume having too many increments on the map. These terminations are discussed in the section on diagnostics (see III.C.6).

6. Flow Diagram (Major Functions)

A flow diagram of the major function of STRAM is given in Figure 11. The long box on the left is the main program containing the executive and trajectory functions. Inside the long box are several nested boxes indicating the structure of the principal set of DO-loops. The major loop is traversed at intervals DTIME from the beginning to the completion of the run. The source loop is traversed once for each plume source. The plume increment loops are traversed once for each increment of the plume from a particular source. The two-step advection loop is a two-step iteration used to find the length in grid units of the interval traversed by one plume increment during the interval DTIME. All the subroutines are shown as smaller rectangles with probes extending into the loop from which they are called. For example, the principal subroutines STRAC and SAMPLE are called from within the source loop in the main program.

The minor subroutines are shown by the smallest size of rectangle. The functions of these subroutines are written immediately adjacent the probe.

7. Executive Control Language and Deck Setup

The following set of control cards is required to execute the STRAM program on the UNIVAC 1110.

STRAM

EXECUTIVE CONTROL LANGUAGE(ECL)

@RUN,PRJ/OPTS RUNID/CORE/TAPE/DISC,ACCT,PROJ/CLASS,RUNTIME,PAGES/CARDS,ETIME

@ASG,T QUAL*RNGRDTAPE,,16H,666666	(ASSIGN RNGRD TAPE)
@USE 1,QUAL*RNGRDTAPE.	(ACCESS RNGRD TAPE ON FORTRAN UNIT 1)
@ASG,T/W QUAL*STRAMTAPE,,16H,777777	(ASSIGN STRAM OUTPUT TAPE)
@USE 3,QUAL*STRAMTAPE.	(WRITE STRAM TAPE ON FORTRAN UNIT3)
@ASG,A QUAL*PROGFILE.	(ASSIGN STRAM PROGRAM FILE)

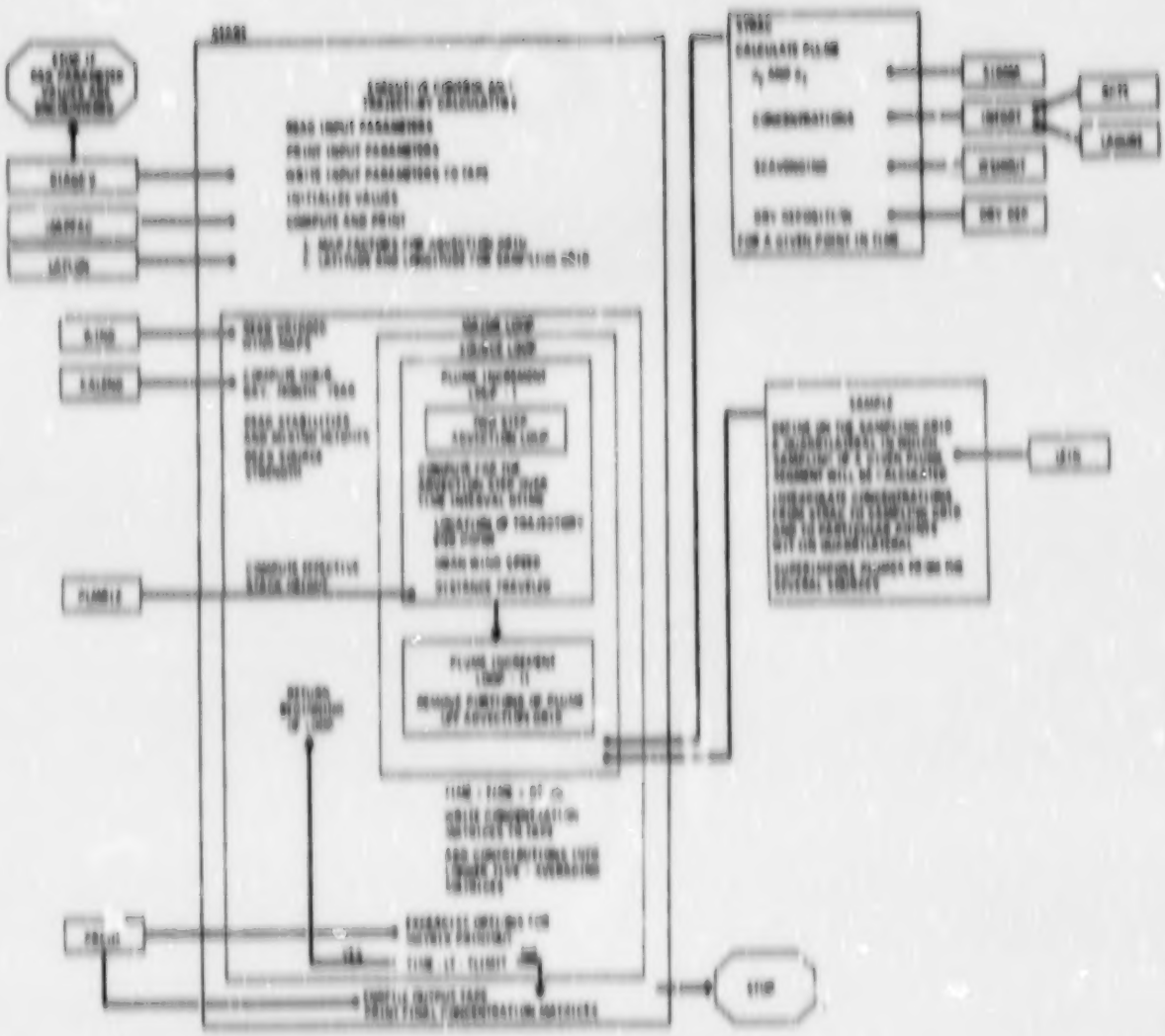


Figure 13. Flow diagram of the major function of STRAH

```
@XQT QUAL*PROGFILE.STRAMPGM          (EXECUTE STRAM ABSOLUTE PROGRAM)

          (INSERT THE DESIRED STRAM CONTROL CARDS HERE)

@FIN
@@
@@
```

NOTE: ALL UNDERLINED PARAMETERS TO BE SUPPLIED BY THE USER, RUN CARD PARAMETERS, QUALIFIERS, FILE NAMES, REEL NUMBERS AND STRAM CONTROL CARD DATA.

4. Input Description and Formats

The input variables are read in either from tape or from cards. In the present version the only data input from a tape is the gridded wind maps. Each information unit consists of a header record, a U-component array and a V-component array that are identical to the output from the Random-to-Grid subroutine described in Section III.B.5.

The read statements in STRAM corresponding to the write statements in Random-to-Grid (see III.B.5) are

```
READ(3)IYR,MON,IDA,IHR,SR,ST,NXA,NX,NYA,NY

READ(3)((U(I,J),I=NXA,NX),J=NYA,NY)

READ(3)((V(I,J),I=NXA,NX),J=NYA,NY)
```

In these statements IYR, MON, IDA, IHR are year, month, day and hour of tape record, SR and ST are heights (see Table 5), NXA and NX are the I subscripts of the initial and final values in the X-direction, and NYA and NY are the J subscripts of the initial and final values in the Y-direction. Actually, NXA and NYA should both be 1. NX and NY should be the dimensions of the array.

TABLE 7. CARD INPUT DESCRIPTION FOR STRAN

Card No.	Columns	Format	Name	Definition
1	1-78	13A6	KKI	Title for matrix CHI
2	1-78	13A6	KKISAV	Title for matrix CHISAV
3	1-78	13A6	KKIMAX	Title for matrix CHIMAX
4	1-78	13A6	KKILAV	Title for matrix CHILAV
5	1-30	6I5	KCOMP	Vector of 6 integers, 0 or 1 to govern output to tape for up to 6 chemical components
6	1-10	F10.0	TLIMIT	Total number of hours for the run
6	11-20	F10.0	DTIME	Number of hours in each basic advection step
6	21-30	F10.0	DMAP	Number of hours between successive wind maps
6	31-40	F10.0	DPRINT	Averaging interval (hours) for routine printout of concentrations
7	1-5	I5	NSOUPCE	Number of source locations
7	6-10	I5	NCOMP	Number of chemical components under analysis
7	11-15	I5	LLX	These four integers are the X and Y
7	16-20	I5	LLY	coordinates on the 47 by 47 NMC grid
7	21-25	I5	MRX	(origin at the north pole) of the
7	26-30	I5	MRY	lower left and upper right corners of the advection grid
7	31-35	I5	IDIV	Number of advection grid linear units per NMC grid linear unit
7	36-40	I5	IMAX	Maximum number of increments that can be considered in one plume
7	41-45	I5	IHR	These four integers are the initial
7	46-50	I5	IDAY	time of the run--hour, day, month,
7	51-55	I5	IMON	year
7	56-60	I5	IYR	
7	61-65	I5	KPRINT	Option, equal 0 or 1, to govern print-out of concentrations at interval DTIME
7	66-70	I5	NRE	Number of nongridded sampling points
7	71-75	I5	JSTAB	Option equal 0 to 1: 0 = read in one 24-hour cycle of stabilities and mixing heights; 1 = read in new stabilities and mixing heights throughout run

TABLE 7 (continued). CARD INPUT DESCRIPTION FOR STRAM

Card No.	Columns	Format	Name	Definition
7	76-80	I5	JSOURC	Option equal 0 or 1; 0 = read in one set of source strengths; 1 = read in new source strengths every interval DTIME
8	1-10	F10.0	XLL	These four numbers are the X and Y coordinates on the advection grid of the lower left and upper right corners of the sampling grid
8	11-20	F10.0	YLL	
8	21-30	F10.0	XUR	
8	31-40	F10.0	YUR	
8	41-50	F10.0	DIV	Number of sampling grid linear units per advection grid linear unit
9	1-5	I5	OPTION	Integer, equal 1 or 2, opting for vertical distribution of pollutants that is (1) Gaussian or (2) even
9	6-10	I5	MODE	Integer, equal 1,2,3,4, indicating mode of analysis pursued in Subroutine STRAC (see glossary)
9	11-20	F10.0	FACTOR	Ratio by which the interval of integration along the plume axis (STRAC) is expanded for each successive step
9	21-30	F10.0	SUBMIN	These two numbers are the minimum
9	31-40	F10.0	SUBMAX	and maximum intervals in cm used in the integrations carried out in STRAC
10	1-60	6E10.0	CBNG	Background levels of concentration for the NCOMP components under analysis-ugm/m^3
11	1-60	6F10.0	WMOLE	Molecular weights for each of the same - gm/mole

INPUT CARDS THAT VARY IN NUMBER

No. of Cards				
NCOMP	1-78	13A6	EPOLUT (KP,I), I=1,13	Names of the individual pollutants, KP=1, NCOMP
NSOURC	1-10	F10.0	SORLAT(S)	Source latitude in degrees,
	11-20	F10.0	SORLON(S)	Source longitude in degrees,
	21-30	F10.0	H(S)	Source height in cm, (S=1, NSOURC)
NRE	1-10	F10.0	RELAT(L)	Receptor latitude in degrees,
	11-20	F10.0	RELON(L)	Receptor longitude in degrees, (L=1, NRE)
varies	varies	I5, F10.0	METABV(I), HMIXV(I)	Stability (1,2,3,4,5,6) and mixing height (cm) prevailing for the interval DTIME
varies	varies	8E10.3	QV(KP,S)	Source strengths for NCOMP components at NSOURC locations for the interval DTIME (gm/sec)

The first four cards give the alphameric title vectors, EXI, EXIMAX, EXISAV, EXILAV, one vector on each card. They are the titles to be printed on the output pages for the matrices CHI, CHIMAX, CHISAV, and CHILAV, respectively. These matrices (each) are dimensioned to output concentrations for six chemical components on a 13 by 13 sampling grid. They are defined as follows:

CHI is the matrix of concentrations averaged over the basic advection interval DTIME, which is the smallest time interval considered in the analysis.

CHISAV is the matrix of concentrations averaged over a longer interval DPRINT. The matrix is zeroed out after each print-out. Each print-out of this matrix is calculated by averaging DPRINT/DTIME contributions from matrix CHI.

CHIMAX is the maximum number occurring in each element of the CHISAV matrix when all the matrices of this kind calculated during a run are considered.

CHILAV is the matrix of concentrations averaged over the entire run.

KOMP is a vector of 6 integers, either 0 or 1. The purpose of this vector is to restrict the number of chemical components, for which the concentrations, CHI are written on output tape. For each nonzero value read into the vector, a corresponding chemical component will be written on the output tape. For example, if the first and fourth members are the only nonzero members in the vector, the first and fourth chemical components will be written to output tape.

The next card is a series of floating point time parameters. All are given in hours.

TLIMIT is the total number of hours for the run.

DTIME is the number of hours in each basic advection step. A typical value is 1. This is also the minimum value compatible with the dimensions and use of METABV.

DMAP is the number of hours between successive wind maps. A typical value is 12.

DPRINT is the arbitrary number of hours chosen for averaging concentrations for the routine print-out. A typical value is 24.

If the suggested values are read in, the program will run through the loop that calculates the trajectories and all the other data TLIMIT times, calculating hourly concentrations each time. There is an option to suppress the print-out of all these hourly concentrations, but not the 24 hour

concentrations, which are routinely printed out. Also, every 12 hours, new maps of the gridded horizontal wind components are read in.

The next card read in consists entirely of integer parameters. NSOURC is the number of source locations. It must not be greater than 10. NCOMP is the number of chemical components under analysis. It must not be greater than 6. The next 4 numbers are X and Y coordinates in the NMC grid system of the lower left and upper right corners of the rectangular portion of the NMC grid chosen for the advection grid. LLX and LLY are the X and Y coordinates, respectively, of the lower left corner. NRX and NRY are the X and Y coordinates, respectively, of the upper right corner. If the rectangle is over the United States, LLY and NRY will both be negative, and LLX will most likely be negative. All 4 of these numbers are found by counting grid intersections from the pole on the NMC map (see III.C.1). IDIV is the number of divisions made of each NMC grid linear unit to create the final advection grid unit. If the advection grid is to have squares with sides half the length of the original NMC squares, IDIV is 2. If no further subdivision is desired, IDIV is 1.

The advection grid is limited to 17 intersections in the horizontal direction and 13 intersections in the vertical direction.

IMAX is the maximum number of increments that can be considered in one plume. As the program is now dimensioned, this number must not be greater than 100.

IHR, IDAY, MON, AND IYER are the initial time for the run--the hour, day, month, and year (minus 1900) as given on the wind tape.

KPRINT is an option governing the printout of hourly average concentration values. If KPRINT is 0, these are omitted. If KPRINT is 1, they are printed out.

NRE indicates the number of particular sampling points that will be included. As the program is now dimensioned, this number cannot be greater than 10. If NRE is zero, the sampling is restricted to grid intersections.

JSTAB and JSOURC are options to curtail the reading of stabilities and mixing heights (JSTAB) and source strengths (JSOURC). If JSTAB = 0, reading one 24-hour cycle of stabilities and mixing heights suffices. This cycle is repeated for every 24-hour period of the analysis. There are 24/DTIME cards, each with one stability value (the integers 1-6 stand for the six Pasquill stability categories A-F) and one mixing height value in cm. If JSTAB is not equal to zero, new values must be read in at interval DTIME throughout the run. If OPTION = 1, the mixing heights may be omitted.

If JSOURC is zero, one set of source strengths for the NCOMP components at the NSOURC locations will suffice. Otherwise, a new set must be read in at each interval DTIME.

These options are made available to curb excessive requirements for card reading inherent in the present version of the program. Ideally these data would be available from tapes on a real time basis throughout the run; but the provision of such data is beyond the scope of the present effort.

The next card read in consists of floating point numbers that locate the sampling grid on the advection grid. XLL and YLL are the X and Y coordinates in the system of the advection grid of the lower left corner of the sampling grid. XUR and YUR are the X and Y coordinates in the system of the advection grid of the upper right corner of the sampling grid. Since the origin of the advection grid is at the lower left corner, all four of these numbers are necessarily non-negative. DIV is the number of divisions made of each advection grid linear unit to create the sampling grid unit. If the sampling grid is to have squares with sides half the length of the advection grid squares, DIV is 2.0. If no further subdivision is desired, DIV is 1.0. The sampling grid is limited to 13 intersections in each direction.

The next card read in contains parameters used by Subroutine STRAC. OPTION is an integer equal to 1 or 2--1 if STRAC is to calculate Gaussian vertical distributions, and 2 if a limited mixing-height is imposed instead.

MODE dictates the calculation sequence in STRAC as indicated in the glossary. FACTOR is the ratio by which the interval of integration along the plume axis is expanded for each successive step. SUBMIN and SUBMAX are the minimum and maximum intervals in cm used in the integrations carried out in STRAC. The initial interval of integration is SUBMIN, following which FACTOR is used to graduate the interval to SUBMAX (or DS(M,N), whichever is smaller, see III.C.1.e). The relation between FACTOR, SUBMIN and SUBMAX just described is reiterated for each increment of each plume every time STRAC is called.

The next card gives the background concentrations for the NCOMP components in $\mu gm/m^3$.

From this point on the number of cards read in varies in accordance with previously entered input parameters. The first set of such cards is the alphameric title matrix for the pollutants, EPOLUT. On each card is read EPOLUT(KP,I),I = 1,13, which is the name of one pollutant. Since the format is 13A6, the name may occupy as many as 78 places. The other index KP varies from 1 to NCOMP, there being NCOMP of these cards.

The next set of cards read in gives the latitudes and longitudes and stack heights of the NSOURC source locations. There is one card for each source location. Each card has for one source latitude, longitude, and the stack height in cm.

The next set of cards gives the latitudes and longitudes of the NRS particular sampling sites. Each card has the latitude and longitude of one such site.

The remainder of the input cards are for stabilities, KSTABV(I), mixing heights PHMV(I), and source strengths QV(KP,K). As explained above, if JSTAB is 0, one 24-hour cycle of stabilities and mixing heights will suffice for a run of arbitrary length since the cycle is repeated for each 24-hour period. Also, if JSOURC is 0, one set of source strength values will suffice for the entire run. Detailed discussion of these inputs has already been given in the discussion of the options JSTAB and JSOURC. The necessary orders of the cards when JSTAB and JSOURC are both zero is illustrated in Section IV.

8. Output Description and Formats

There are two output files, one to line printer and one to tape. The outputs will be discussed in the order of their occurrence within the program. The write statements to tape are unformatted. The number of successively written output tapes per run will depend on the length of the run and will have to be determined by the user. Examples of output to line printer are given in Section IV.

The first printing consists of most of the input parameters just described. The formats are arranged so that the numbers are in place within descriptive sentences.

Immediately following this output, a Subroutine DIAGNO is called, wherein several of the input parameter values are tested for reasonableness. If one of these values is out of range, it is printed out along with its name, and the program is stopped. The output of this subroutine is described in detail in III.C.8.

If the Subroutine DIAGNO is executed without stopping the run, the input parameters are written to tape in three unformatted write statements. They are:

First write statement to tape:

```
NSOURC, NCOMP, LLX, LLY, NMX, NMY, IDIV, IHR,
IDAY, IMON, IYER, OPTION, MODE
```

Second write statement to tape:

```
TLIMIT, DTIME, DMAP, XLL, YLL, XUR, YUR, DIV,
DM, DMS, (XSOURC(K), YSOURC(K), H(K), K = 1,10)
```

Third write statement to tape:

```
NRE, NELAT, NELON,
```

All these items except DM, DMS, XSOURC and YSOURC are read-in parameters and are defined in the previous section on the input parameters. DM is the basic distance in centimeters between consecutive grid intersections on the advection grid. DMS is the same for the sampling grid. The derivation of the corresponding actual scales on the grids as functions of latitude is

discussed in the earlier descriptive section on the entire code. XSOURC and YSOURC are X and Y coordinates of source positions on the advection grid.

The latitudes and longitudes of the intersections of the sampling grid are also printed out.

The remainder of the output to line printer is the information on concentrations, both gridded and at particular sites.

The routine print-out of concentration matrices is one set, containing one matrix for each chemical component, printed out for each DPRINT hours. The concentrations in each matrix are averaged over DPRINT hours. Typically DPRINT may equal 24. After each print-out, the matrix is zeroed out so that averaging can begin for the next period of DPRINT hours.

Since each concentration matrix is limited for each chemical component to a grid of 13 by 13 points, they are easily printed out on one page. Such a page has

(1) a heading indicating the type of matrix (averaged over DPRINT hours;

(2) name of the chemical component average concentrations;

(3) the time and date at the end of the averaging interval;

(4) the average concentration matrix in E format. Concentrations are in micrograms per m^3 at ground level;

(5) additional print-out of the largest number on the matrix.

If in addition there is sampling at particular locations, the page contains

(1) a heading so indicating;

(2) X- and Y-coordinates on sampling grid of each particular location;

(3) the average concentration at each such location.

Pages of exactly the same format are printed out for three other types of concentration matrices. These pages differ in appearance only by the page headings that describe what type of concentration matrix is being printed out. At the end of the run two or three types of concentration matrices

are printed out. One gives the maximum concentration for each chemical component averaged over a period of DPRINT hours that occurred at each sampling location. The other type is the average concentration for the entire period of the run for each chemical component and at each sampling location.

In addition there is an option to print out all the concentration matrices for the basic advection interval DTIME (typically 1 hour). If this option is desired, the number of pages of associated printed output should be anticipated before running the program this way.

The concentrations averaged over DTIME hours are also written unformatted to tape, both for the grid and for the particular locations. The chemical component, indicated by N and the time and date, indicated by JHR, JDAY, JMON, and JYER, are also included. The two write statements are:

```
WRITE(3)TIME,KP,WHOLE(FF),((CHI(KP,I,J),I=1,MSX),J=1,MSY);

IF(NRE.NE.0)WRITE(3)(CH(KP,L),L=1,NRE)
```

The CHI matrix is for the grid, and the CH matrix is for the particular sampling locations. Concentrations are in gram moles/m^3. At the completion of the run an end-of-file is written on this tape.

6. Diagnostics

There are a number of diagnostic messages printed out from a Subroutine DIAGNO. This subroutine checks a number of the input parameters for reasonable values. If one of them is found to be outside of a prescribed range, a message is printed out and the run stops before any trajectory or dispersion calculation is made.

The subroutine does not print descriptive statements but simply prints out the unacceptable parameter's name, the parameter value and the acceptable range. The user must make his own diagnosis from his knowledge of the definitions of the input parameters, and from the brief descriptive write-up to follow here. Diagnostics on NSOURC and NCOMP indicate that either (1) a value has been entered that exceeds the dimensioned capacity or (2) inadvertantly a zero or negative value has been entered. The maximum allowable values for NSOURC and NCOMP are 10 and 6, respectively.

NX and NY are the number of intersections in the X and Y directions, respectively, of the advection grid. These are limited by the current dimension statements to 17 and 13, respectively. They are calculated from the values read in of the lower left (LLX,LLY) and upper right (MRX,MRY) corner coordinates on the MMC grid of the advection grid and from IDIV, which indicates the subdivision of the MMC grid made to form the advection grid. If the values exceed this capacity, or are less than two, they are printed out, and the program is stopped.

NSX and NSY are the number of intersections in the horizontal and vertical dimensions on the sampling grid. They are limited by current dimension statements to 13 each. They are calculated by the program from the dimensions of the advection grid and the further subdivision made of it. If they exceed 13 or are less than 2, the values are printed out and the program stops.

LLX and LLY are the coordinates in the NMC grid system of the lower left corner of the advection grid. Since we use a right-handed system with the origin at the pole, the positive Y axis pointing upward and the positive X axis point rightward, both coordinates of the lower left corner of a rectangle over the United States are usually negative--always so for the Y-coordinate, LLY. The diagnostics for LLX and LLY are designed to stop a run if the specified location of the rectangle is obviously not over the United States or Canada. Such an error could be made simply by neglecting the negative signs. Thus, if the user wants the rectangle over some other portion of the northern hemisphere, these diagnostic statements must be removed from the program.

The source coordinates (XSOURC(I), YSOURC(I)) are computed from inputs of longitude and latitude, respectively. The coordinates of the particular receptor sites (XREC(L),YREC(L)) are computed from the same type input data. Subroutine DIAGNO checks all these. If any are found to be off the advection grid, the index (the I or L above) of any such source and/or receptor location is printed out and the run stopped.

While these diagnostic statements do not make the program foolproof, they do prevent execution in case of some of the most obvious errors.

There are other cases in which a diagnostic message may be printed out during the course of the trajectory and dispersion calculations. This occurs if for some reason the run cannot be continued. In this case the run terminates by calculating average concentrations for the portion of the run executed. An end-of-file mark is also put on the output tape.

There are two cases in which this may occur. One is if an end-of-file mark is encountered on the wind tape. Another is if the number of increments remaining on the map for one of the plumes exceeds the dimension (currently set at 100). If premature termination occurs for either reason, the effective hour and date at the termination as well as the total number of hours in the run are printed out by the line printer.

The user should be aware that for prolonged periods of light wind conditions the number of increments per plume on the advection grid may exceed 100. Possible solutions to this problem should be considered in advance.

In its present form the program occupies about 44000 core locations in the CDC-66000 version. If the allotment of increments per plume is increased by redimensioning, 322 more locations will be required for each additional

increment allowed per plume. Thus, if the allotment is raised from 100 to 300, 33300 more core locations will be required, bringing the total to more than 65000.

If this is prohibitive and no smaller allotment seems safe, one of the following alternatives may be considered:

(i) The only way to effect a major reduction in core requirements if the allotment of increments per plume is increased is to reduce the number of sources.

(ii) The core demands of this problem may be reduced by making the advection grid representative of a smaller area.

SECTION IV

INSTALLATION - TEST RUN

A. RANDOM-TO-GRID TEST RUN

The following test run of the Random-to-Grid program is included for the purpose of providing an example against which the user can make a comparison with a run on the computer to which he has access.

1. Input Data

a. From Tape

The data tape used to produce this example consists of pibal and rawinsonde data reduced from ETAC Upper Air data tapes by the NOAA Air Resources Laboratory and converted for use on a Univac 1110 computer.

b. From Cards

The content of each card of input data is tabulated below in Table 8.

TABLE 8. CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
1	1-64	16A4	ITLE	TEST OF HAMER TAPE FORMAT
2	1-5	I5	NP	45
2	6-10	I5	NSX	1
2	11-15	I5	NSY	1
2	16-20	I5	NPX	13
2	21-25	I5	NPY	9
2	26-30	I5	KTAPE	1
2	31-35	I5	NSTL	3
2	36-40	I5	IHT	1
3	1-5	I5	KSX(1)	1
3	6-10	I5	KSX(2)	1
3	11-15	I5	KSX(3)	1
3	16-20	I5	KSX(4)	1
3	21-25	I5	KSX(5)	1
3	26-30	I5	KSX(6)	1
3	31-35	I5	KSX(7)	1
3	36-40	I5	KSX(8)	1
3	41-45	I5	KSX(9)	1
3	46-50	I5	KSX(10)	1
3	51-55	I5	KSX(11)	1
3	56-60	I5	KSX(12)	1

TABLE 8 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphanumeric specification)
3	61-65	I5	KSK(13)	1
3	66-70	I5	KSK(14)	1
3	71-75	I5	KSK(15)	1
3	76-80	I5	KSK(16)	1
4	1-5	I5	MFK(1)	13
4	6-10	I5	MFK(2)	13
4	11-15	I5	MFK(3)	13
4	16-20	I5	MFK(4)	13
4	21-25	I5	MFK(5)	13
4	26-30	I5	MFK(6)	13
4	31-35	I5	MFK(7)	13
4	36-40	I5	MFK(8)	13
4	41-45	I5	MFK(9)	13
4	46-50	I5	MFK(10)	13
4	51-55	I5	MFK(11)	13
4	56-60	I5	MFK(12)	13
4	61-65	I5	MFK(13)	13
4	66-70	I5	MFK(14)	13
4	71-75	I5	MFK(15)	13
4	76-80	I5	MFK(16)	13
5	1-10	F10.0	RUN	0.0
5	11-20	F10.0	RHMC	21.0
5	21-30	F10.0	VHMC	0.0
5	31-40	F10.0	RFU	.5
5	41-50	F10.0	THET	0.0
6	1-5	I5	KSTA(1)	2129
6	6-10	I5	KSTA(2)	2304
6	11-15	I5	KSTA(3)	2311
6	16-20	I5	KSTA(4)	2317
6	21-25	I5	KSTA(5)	2327
6	26-30	I5	KSTA(6)	2340
6	31-35	I5	KSTA(7)	2349
6	36-40	I5	KSTA(8)	2355
6	41-45	I5	KSTA(9)	2357
6	46-50	I5	KSTA(10)	2402
6	51-55	I5	KSTA(11)	2403
6	56-60	I5	KSTA(12)	2408
6	61-65	I5	KSTA(13)	2414
6	66-70	I5	KSTA(14)	2425
6	71-75	I5	KSTA(15)	2429
6	76-80	I5	KSTA(16)	2433

TABLE 8 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or Alphameric specification)
6	1-5	I5	KSTA(17)	3451
6	6-10	I5	KSTA(18)	3466
6	11-15	I5	KSTA(19)	3518
6	16-20	I5	KSTA(20)	3590
6	21-25	I5	KSTA(21)	3598
6	26-30	I5	KSTA(22)	3599
6	31-35	I5	KSTA(23)	3534
6	36-40	I5	KSTA(24)	3553
6	41-45	I5	KSTA(25)	3606
6	46-50	I5	KSTA(26)	3627
6	51-55	I5	KSTA(27)	3637
6	56-60	I5	KSTA(28)	3645
6	61-65	I5	KSTA(29)	3654
6	66-70	I5	KSTA(30)	3655
6	71-75	I5	KSTA(31)	3701
6	76-80	I5	KSTA(32)	3713
6	1-5	I5	KSTA(33)	3722
6	6-10	I5	KSTA(34)	3734
6	11-15	I5	KSTA(35)	3747
6	16-20	I5	KSTA(36)	3811
6	21-25	I5	KSTA(37)	3826
6	26-30	I5	KSTA(38)	3836
6	31-35	I5	KSTA(39)	3845
6	36-40	I5	KSTA(40)	3852
6	41-45	I5	KSTA(41)	3853
6	46-50	I5	KSTA(42)	4399
6	51-55	I5	KSTA(43)	4400
6	56-60	I5	KSTA(44)	4494
6	61-65	I5	KSTA(45)	4695
7	1-5	F5.2	X(1)	33.57
7	6-10	F5.2	X(2)	35.27
7	11-15	F5.2	X(3)	33.95
7	16-20	F5.2	X(4)	36.08
7	21-25	F5.2	X(5)	36.35
7	26-30	F5.2	X(6)	34.73
7	31-35	F5.2	X(7)	36.66
7	36-40	F5.2	X(8)	34.60
7	41-45	F5.2	X(9)	35.23
7	46-50	F5.2	X(10)	37.85
7	51-55	F5.2	X(11)	38.98
7	56-60	F5.2	X(12)	39.88
7	61-65	F5.2	X(13)	38.17
7	66-70	F5.2	X(14)	38.17
7	71-75	F5.2	X(15)	39.87
7	76-80	F5.2	X(16)	38.65

TABLE 6 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphanumeric specification)
7	1-5	F5.2	X(17)	37.77
7	6-10	F5.2	X(18)	39.07
7	11-15	F5.2	X(19)	40.75
7	16-20	F5.2	X(20)	40.83
7	21-25	F5.2	X(21)	42.93
7	26-30	F5.2	X(22)	40.67
7	31-35	F5.2	X(23)	41.78
7	36-40	F5.2	X(24)	41.37
7	41-45	F5.2	X(25)	43.65
7	46-50	F5.2	X(26)	45.47
7	51-55	F5.2	X(27)	42.97
7	56-60	F5.2	X(28)	44.48
7	61-65	F5.2	X(29)	44.38
7	66-70	F5.2	X(30)	45.58
7	71-75	F5.2	X(31)	45.83
7	76-80	F5.2	X(32)	46.87
7	1-5	F5.2	X(33)	46.37
7	6-10	F5.2	X(34)	46.47
7	11-15	F5.2	X(35)	48.57
7	16-20	F5.2	X(36)	50.22
7	21-25	F5.2	X(37)	53.20
7	26-30	F5.2	X(38)	51.27
7	31-35	F5.2	X(39)	53.83
7	36-40	F5.2	X(40)	49.90
7	41-45	F5.2	X(41)	49.02
7	46-50	F5.2	X(42)	43.76
7	51-55	F5.2	X(43)	40.65
7	56-60	F5.2	X(44)	41.67
7	61-65	F5.2	X(45)	35.68
8	1-5	F5.2	V(1)	66.75
8	6-10	F5.2	V(2)	75.65
8	11-15	F5.2	V(3)	81.32
8	16-20	F5.2	V(4)	79.95
8	21-25	F5.2	V(5)	86.57
8	26-30	F5.2	V(6)	92.23
8	31-35	F5.2	V(7)	93.90
8	36-40	F5.2	V(8)	98.40
8	41-45	F5.2	V(9)	97.47
8	46-50	F5.2	V(10)	75.48
8	51-55	F5.2	V(11)	77.47
8	56-60	F5.2	V(12)	75.35
8	61-65	F5.2	V(13)	81.60
8	66-70	F5.2	V(14)	82.55
8	71-75	F5.2	V(15)	84.12
8	76-80	F5.2	V(16)	88.97

TABLE 8 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
8	1-5	F5.2	V(17)	99.97
8	6-10	F5.2	V(18)	95.63
8	11-15	F5.2	V(19)	73.80
8	16-20	F5.2	V(20)	80.23
8	21-25	F5.2	V(21)	78.73
8	26-30	F5.2	V(22)	89.68
8	31-35	F5.2	V(23)	87.75
8	36-40	F5.2	V(24)	96.02
8	41-45	F5.2	V(25)	70.32
8	46-50	F5.2	V(26)	73.78
8	51-55	F5.2	V(27)	83.73
8	56-60	F5.2	V(28)	88.13
8	61-65	F5.2	V(29)	98.02
8	66-70	F5.2	V(30)	94.07
8	71-75	F5.2	V(31)	86.43
8	76-80	F5.2	V(32)	68.02
8	1-5	F5.2	V(33)	75.98
8	6-10	F5.2	V(34)	84.37
8	11-15	F5.2	V(35)	93.38
8	16-20	F5.2	V(36)	66.87
8	21-25	F5.2	V(37)	90.90
8	26-30	F5.2	V(38)	80.65
8	31-35	F5.2	V(39)	89.87
8	36-40	F5.2	V(40)	97.53
8	41-45	F5.2	V(41)	99.65
8	46-50	F5.2	V(42)	85.25
8	51-55	F5.2	V(43)	73.78
8	56-60	F5.2	V(44)	89.97
8	61-65	F5.2	V(45)	75.90
9	1-5	1X,A4	NAME1(1)	3328
9	6-10	1X,A4	NAME1(2)	3304
9	11-15	1X,A4	NAME1(3)	3311
9	16-20	1X,A4	NAME1(4)	3317
9	21-25	1X,A4	NAME1(5)	3327
9	26-30	1X,A4	NAME1(6)	3340
9	31-35	1X,A4	NAME1(7)	3349
9	36-40	1X,A4	NAME1(8)	3355
9	41-45	1X,A4	NAME1(9)	3357
9	46-50	1X,A4	NAME1(10)	3402
9	51-55	1X,A4	NAME1(11)	3401
9	56-60	1X,A4	NAME1(12)	3408
9	61-65	1X,A4	NAME1(13)	3414
9	66-70	1X,A4	NAME1(14)	3425
9	71-75	1X,A4	NAME1(15)	3429
9	76-80	1X,A4	NAME1(16)	3433

TABLE 8 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphanumeric specification)
9	1-5	1X,A4	HAMSI(17)	2451
9	6-10	1X,A4	HAMSI(18)	2456
9	11-15	1X,A4	HAMSI(19)	2510
9	16-20	1X,A4	HAMSI(20)	2520
9	21-25	1X,A4	HAMSI(21)	2528
9	26-30	1X,A4	HAMSI(22)	2532
9	31-35	1X,A4	HAMSI(23)	2534
9	36-40	1X,A4	HAMSI(24)	2553
9	41-45	1X,A4	HAMSI(25)	2606
9	46-50	1X,A4	HAMSI(26)	2607
9	51-55	1X,A4	HAMSI(27)	2617
9	56-60	1X,A4	HAMSI(28)	2645
9	61-65	1X,A4	HAMSI(29)	2654
9	66-70	1X,A4	HAMSI(30)	2655
9	71-75	1X,A4	HAMSI(31)	2701
9	76-80	1X,A4	HAMSI(32)	2718
9	1-5	1X,A4	HAMSI(33)	2720
9	6-10	1X,A4	HAMSI(34)	2734
9	11-15	1X,A4	HAMSI(35)	2747
9	16-20	1X,A4	HAMSI(36)	2811
9	21-25	1X,A4	HAMSI(37)	2826
9	26-30	1X,A4	HAMSI(38)	2836
9	31-35	1X,A4	HAMSI(39)	2846
9	36-40	1X,A4	HAMSI(40)	2853
9	41-45	1X,A4	HAMSI(41)	2853
9	46-50	1X,A4	HAMSI(42)	4139
9	51-55	1X,A4	HAMSI(43)	4486
9	56-60	1X,A4	HAMSI(44)	4494
9	61-65	1X,A4	HAMSI(45)	4695
10	1-4	A4	FMON(1)	JAN
10	5-8	A4	FMON(2)	FEB
10	9-12	A4	FMON(3)	MAR
10	13-16	A4	FMON(4)	APR
10	17-20	A4	FMON(5)	MAY
10	21-24	A4	FMON(6)	JUN
10	25-28	A4	FMON(7)	JUL
10	29-32	A4	FMON(8)	AUG
10	33-36	A4	FMON(9)	SEP
10	37-40	A4	FMON(10)	OCT
10	41-44	A4	FMON(11)	NOV
10	45-48	A4	FMON(12)	DEC

TABLE 6 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
11	1-5	I5	IVS	74
11	6-10	I5	MS	4
11	11-15	I5	IDS	5
11	16-20	I5	IHS	0
11	21-25	I5	IVL	74
11	26-30	I5	ML	4
11	31-35	I5	IDL	5
11	36-40	I5	IHL	0
11	41-45	I5	KNTHR	0
11	46-50	I5	KREN	0
12	1-5	F5.0	SS	100.
12	6-10	F5.0	ST	1000.
13	1-10	F10.1	FLATHR	13.0
13	11-20	F10.1	FLATMR	54.0
13	21-30	F10.1	FLOHMH	65.0
13	31-40	F10.0	FLOHMR	100.0
13	41-45	I5	IDT	12

3. Output Data

The resulting output is shown on the following pages.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	Station Elevation	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B. STRAM TEST RUN

The following test run of the STRAM program is included for the purpose of providing an example against which the user can make a comparison with a run on the computer to which he has access. The run will be 24 hours in length, the basic advection and sampling interval will be 1 hour, the short term averaging matrix CHISAV will be averaged over 12 hours, and wind maps will be read in every 12 hours. Core requirement is 45000.

1. Input Data

a. From Tape

The data tape used to produce this example was produced by the Random-to-Grid program using an original tape supplied by the Air Resources Laboratories at Silver Springs, Maryland (see III.E.1). The tape so-produced is a standard label 9-track tape written at 1600 bpi.

b. From Cards

The contents of each card of input data is tabulated below in Table 9.

TABLE 9. CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
1	1-78	13A6	KKI	CONCENTRATIONS AVERAGED OVER BASIC ADVECTION STEP DTIME
2	1-78	13A6	KKISAV	CONCENTRATIONS AVERAGED OVER STANDARD INTERVAL DPRINT
3	1-78	13A6	KKIMAX	MAXIMUM VALUES OVER THE CHISAV MATRICES
4	1-78	13A6	KKILAV	CONCENTRATIONS AVERAGED OVER THE ENTIRE RUNNING TIME TLIMIT
5	1-30	6I5	KCOMP	0 0 0 0 0 0
6	1-10	F10.0	TLIMIT	24.
6	11-20	F10.0	DTIME	1.
6	21-30	F10.0	DMAP	12.
6	31-40	F10.0	DPRINT	12.
7	1-5	I5	NSOURC	2
7	6-10	I5	NCOMP	2
7	11-15	I5	LLX	-3
7	16-20	I5	LLY	-16

TABLE 4 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
7	21-25	I5	NRX	3
7	26-30	I5	NAV	-13
7	31-35	I5	IDIV	2
7	36-40	I5	IMAX	100
7	41-45	I5	IHR	0
7	46-50	I5	IDAY	5
7	51-55	I5	IMON	4
7	56-60	I5	ITER	74
7	61-65	I5	KPRINT	0
7	66-70	I5	NRE	2
7	71-75	I5	JSTAB	0
7	76-80	I5	JSOURC	0
8	1-10	F10.0	XLL	1.
8	11-20	F10.0	YLL	1.
8	21-30	F10.0	XUR	4.
8	31-40	F10.0	YUR	4.
8	41-50	F10.0	DIV	4.
9	1-5	I5	OPTION	2
9	6-10	I5	MODE	5
9	11-20	F10.0	FACTOR	2.
9	21-30	F10.0	SUBMIN	350000.
9	31-40	F10.0	SUBMAX	5000000.
10	1-60	6F10.0	CBKG	0. 1.
11	1-20	2F10.0	WHOLE	64. 95.
12	1-78	13A6	KPOLUT	SULFUR DIOXIDE
13	1-78	13A6		SULFATE
14	1-10	F10.0	SORLAT(1)	41.00
14	11-20	F10.0	SORLON(1)	89.50
14	21-30	F10.0	HS(1)	0.
15	1-10	F10.0	SORLAT(2)	37.00
15	11-20	F10.0	SORLON(2)	86.00
15	21-30	F10.0	HS(2)	0.
16	1-10	F10.0	RELAT(1)	40.00
16	11-20	F10.0	RELON(1)	89.00
17	1-10	F10.0	RELAT(2)	38.00
17	11-20	F10.0	RELON(2)	88.00
18	1-5	I5	METANV(1)	6
18	6-15	F10.0	HHMV(1)	70000.
19	1-10	E10.0	QV(1,1)	1.0E4
19	11-20	E10.0	QV(2,1)	1.0E2
19	21-30	E10.0	QV(1,2)	1.0E4
19	31-40	E10.0	QV(2,2)	1.0E2

TABLE 9 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
20	1-5	I5	METABV(2)	6
20	6-15	F10.0	HHMV(2)	60000.
21	1-5	I5	METABV(3)	6
21	6-15	F10.0	HHMV(3)	50000.
22	1-5	I5	METABV(4)	6
22	6-15	F10.0	HHMV(4)	40000.
23	1-5	I5	METABV(5)	6
23	6-15	F10.0	HHMV(5)	30000.
24	1-5	I5	METABV(6)	6
24	6-15	F10.0	HHMV(6)	20000.
25	1-5	I5	METABV(7)	4
25	6-15	F10.0	HHMV(7)	40000.
26	1-5	I5	METABV(8)	4
26	6-15	F10.0	HHMV(8)	70000.
27	1-5	I5	METABV(9)	4
27	6-15	F10.0	HHMV(9)	90000.
28	1-5	I5	METABV(10)	3
28	6-15	F10.0	HHMV(10)	120000.
29	1-5	I5	METABV(11)	3
29	6-15	F10.0	HHMV(11)	140000.
30	1-5	I5	METABV(12)	3
30	6-15	F10.0	HHMV(12)	150000.
31	1-5	I5	METABV(13)	3
31	6-15	F10.0	HHMV(13)	160000.
32	1-5	I5	METABV(14)	3
32	6-15	F10.0	HHMV(14)	170000.
33	1-5	I5	METABV(15)	3
33	6-15	F10.0	HHMV(15)	180000.
34	1-5	I5	METABV(16)	3
34	6-15	F10.0	HHMV(16)	180000.
35	1-5	I5	METABV(17)	3
35	6-15	F10.0	HHMV(17)	170000.
36	1-5	I5	METABV(18)	4
36	6-15	F10.0	HHMV(18)	160000.
37	1-5	I5	METABV(19)	5
37	6-15	F10.0	HHMV(19)	140000.

TABLE 9 (continued). CARD INPUT FOR TEST RUN

Card No.	Columns	Format	Name	Value (or alphameric specification)
38	1-5	I5	MSTABV(20)	5
38	6-15	F10.0	HHMV(20)	120000.
39	1-5	I5	MSTABV(21)	5
39	6-15	F10.0	HHMV(21)	100000.
40	1-5	I5	MSTABV(22)	5
40	6-15	F10.0	HHMV(22)	90000.
41	1-5	I5	MSTABV(23)	5
41	6-15	F10.0	HHMV(23)	80000.
42	1-5	I5	MSTABV(24)	5
42	6-15	F10.0	HHMV(24)	70000.

Cards 17 through 41 simulate with card input the more desirable situation in which there would be hourly input from one tape of stability MSTABV (ITIME) and mixing height HHMV(ITIME) and hourly input from another tape of source strength QV(KP,K) for each component KP at each source K. The particular numbers in MSTABV and HHMV in this example are arbitrary but typical of conditions in the temperate latitudes under clear skies, if one assumes a sinusoidal cycle of mixing height as is commonly advocated.[9]

Other parameter values are input by the code. They are

1. The rate constants:

   FUNCT(J,1) = -5.56E-6*C(1)

   FUNCT(J,2) = -FUNCT(J,1)

2. The deposition velocities are given by:

   VD(1) = 1.0

   VD(2) = 0.1

   in cm sec^{-1}.

4. The washout coefficients are given by:

WOU(1) = 0.

WOU(2) = 0.

5. Output Data

The resulting output is shown in the following pages.

[redacted] TRANSPORT RECEPTOR ANALYSIS MODEL

[redacted] TIME FOR Run IS 24. HOURS.
BASIC TIME INCREMENT IS 1. HOURS. MAP INTERVAL IS 12. HOURS.
AVERAGING INTERVAL BETWEEN PRINTED RUNOFF SERIES IS 12.0 HOURS

THERE ARE 2 SOURCE LOCATIONS.
LATITUDES- LONGITUDES- X AND Y COORDINATES IN THE ADVECTION GRID, AND EFFECTIVE STACK HEIGHTS ARE
42.00 89.50 1.31 3.97 0. CM.
37.00 84.50 2.75 1.87 0. CM.
2 CHEMICAL COMPONENTS ARE ANALYZED.
MOLECULAR WEIGHTS ARE 64.0 96.0
BACKGROUND CONCENTRATIONS IN MOLES/(CM**3) .78E10-13 .29E05-13
THE GRID IS DERIVED FROM THE NMC 47 BY 47 GRID BY SELECTING A RECTANGULAR PORTION AND PUNCHING SUBSYNOPTICAL.
THE COORDINATES IN THE NMC GRID OF THE LOWER LEFT CORNER OF THE RECTANGLE ARE -3 -3.
THESE ARE SPECIFIED WITH RESPECT TO A RIGHT HANDED COORDINATE SYSTEM WITH THE ORIGIN AT THE POLE.
THE NEGATIVE Y AXIS EXTENDS DOWNWARD ALONG THE MERIDIAN 80 DEGREES WEST.
THE AREA OF THE RECTANGLE IS 6 BY 6 NMC GRID SQUARES.
THIS AREA IS DIVIDED INTO 12 BY 12 SQUARES TO FORM THE ADVECTION GRID.
THE COORDINATES IN THE ADVECTION GRID OF THE LOWER LEFT AND UPPER RIGHT CORNERS OF THE SAMPLING GRID ARE
1.0 1.0 AND 4.0 4.0 RESPECTIVELY.
THE SAMPLING GRID IS DIVIDED INTO 12.0 BY 12.0 SQUARES
SPACE SAMPLING IS AT INTERSECTIONS The SAMPLING MATRIX IS 13 BY 13.
IN ADDITION THERE ARE 2 PARTICULARLY SPECIFIED SAMPLING LOCATIONS.
LATITUDES- LONGITUDES- X AND Y COORDINATES IN THE ADVECTION GRID ARE
40.00 88.00 1.45 3.28
38.00 85.35 3.35 1.76
X AND Y COORDINATES OF THE PARTICULAR LOCATIONS IN THE SAMPLING GRID ARE
1.45 9.28
9.46 2.76

THE STEP PARAMETERS DT[illegible] AND MAP ARE 2 4. FACTOR IS 2.0.
SHORTER AND SHORTER ARE 250000. 500000.

THE BASIC SQUARE LENGTH IN THE ADVECTION GRID IS 190.50 KM.
THE BASIC SQUARE LENGTH IN THE SAMPLING GRID IS 47.63 KM.

THE INITIAL TIME IS 9 5 4 76 (MONDAY,SEPTEMBER,4)

MAP FACTORS
1.0966 1.0977 1.0975 1.0973 1.0972 1.0971 1.0971 1.0971 1.0972 1.0973 1.0975 1.0977 1.0980
1.0962 1.0969 1.0967 1.0965 1.0964 1.0963 1.0963 1.0963 1.0964 1.0965 1.0967 1.0969 1.0972
1.0954 1.0961 1.0959 1.0957 1.0956 1.0955 1.0955 1.0955 1.0956 1.0957 1.0959 1.0961 1.0964
1.0937 1.0944 1.0942 1.0940 1.0939 1.0938 1.0938 1.0938 1.0938 1.0940 1.0942 1.0944 1.0947
1.0906 1.0917 1.0915 1.0913 1.0912 1.0911 1.0911 1.0911 1.0912 1.0913 1.0915 1.0917 1.0920
1.0843 1.0861 1.0859 1.0857 1.0856 1.0855 1.0855 1.0855 1.0856 1.0857 1.0859 1.0861 1.0863
1.0719 1.0755 1.0753 1.0751 1.0750 1.0749 1.0749 1.0749 1.0750 1.0751 1.0753 1.0755 1.0758
1.0472 1.0578 1.0567 1.0566 1.0564 1.0564 1.0564 1.0564 1.0564 1.0566 1.0567 1.0578 1.0572
1.0247 1.0385 1.0382 1.0381 1.0380 1.0379 1.0379 1.0379 1.0380 1.0381 1.0382 1.0385 1.0387

[illegible]

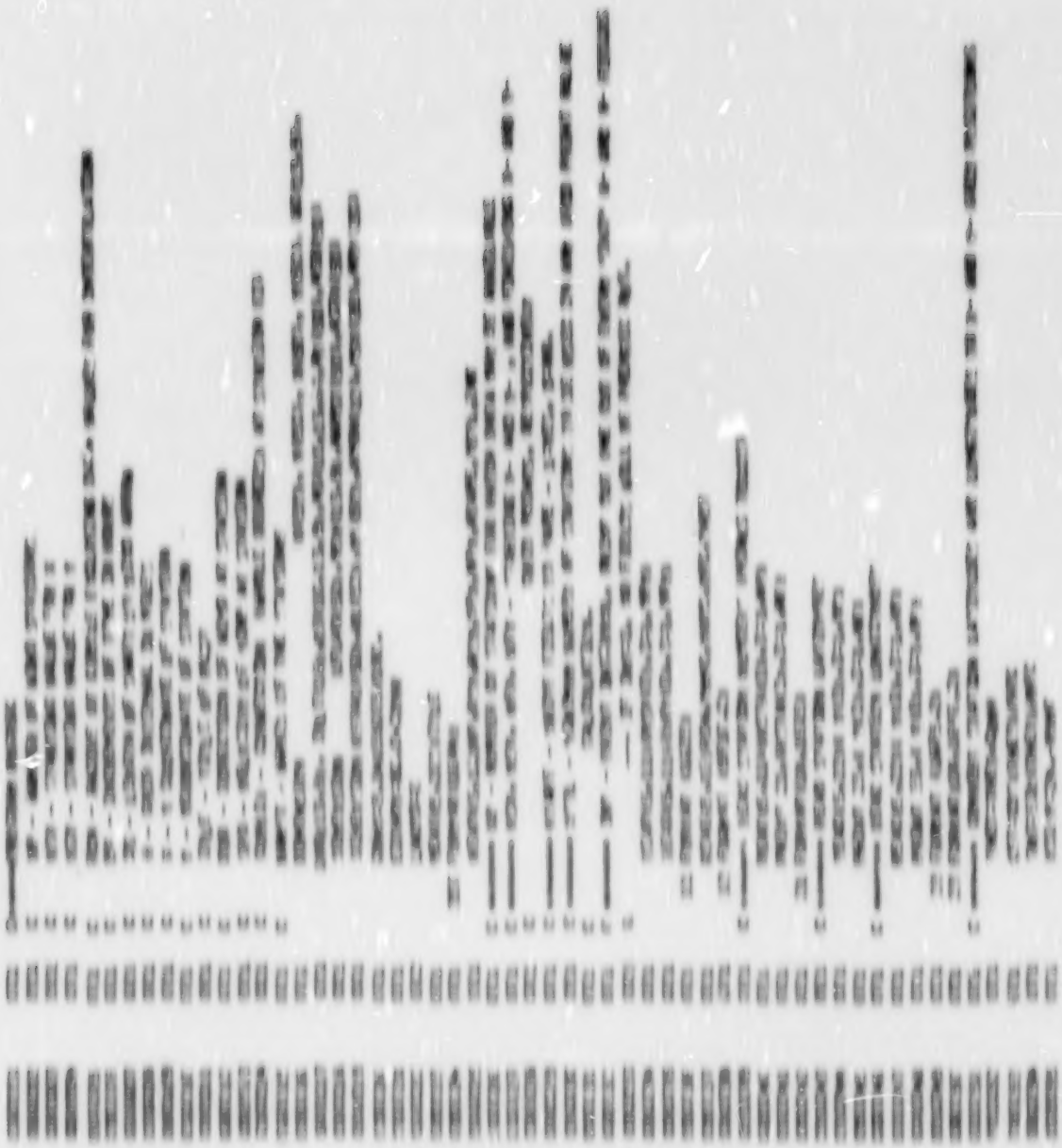
[illegible]

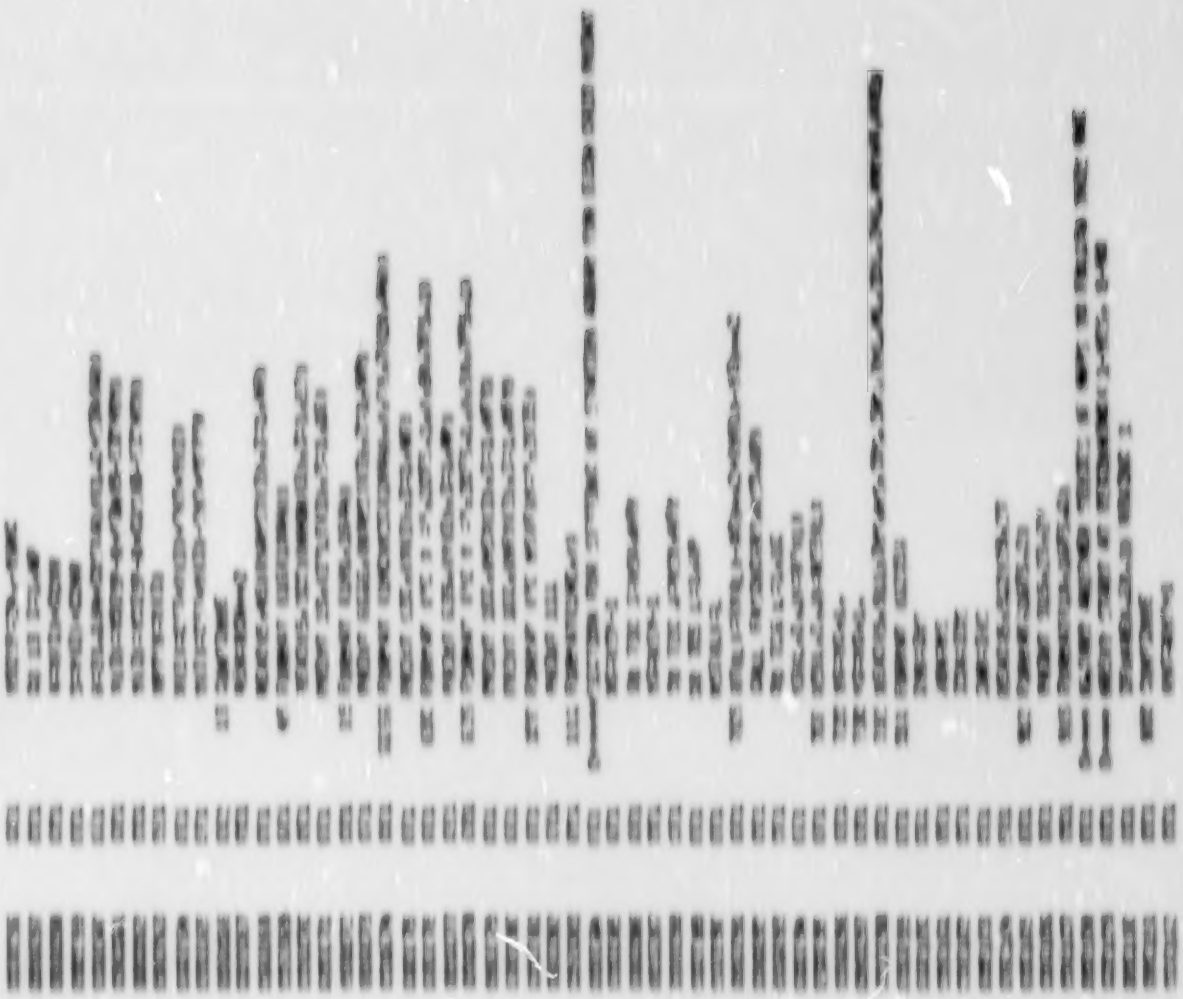
[illegible]

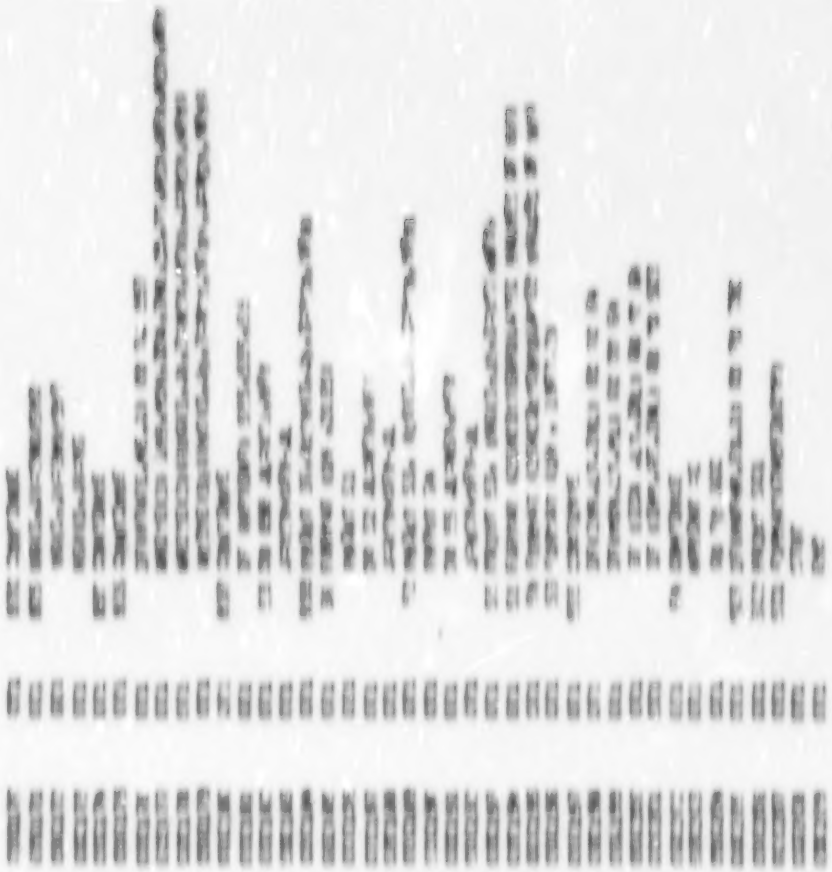
SECTION V

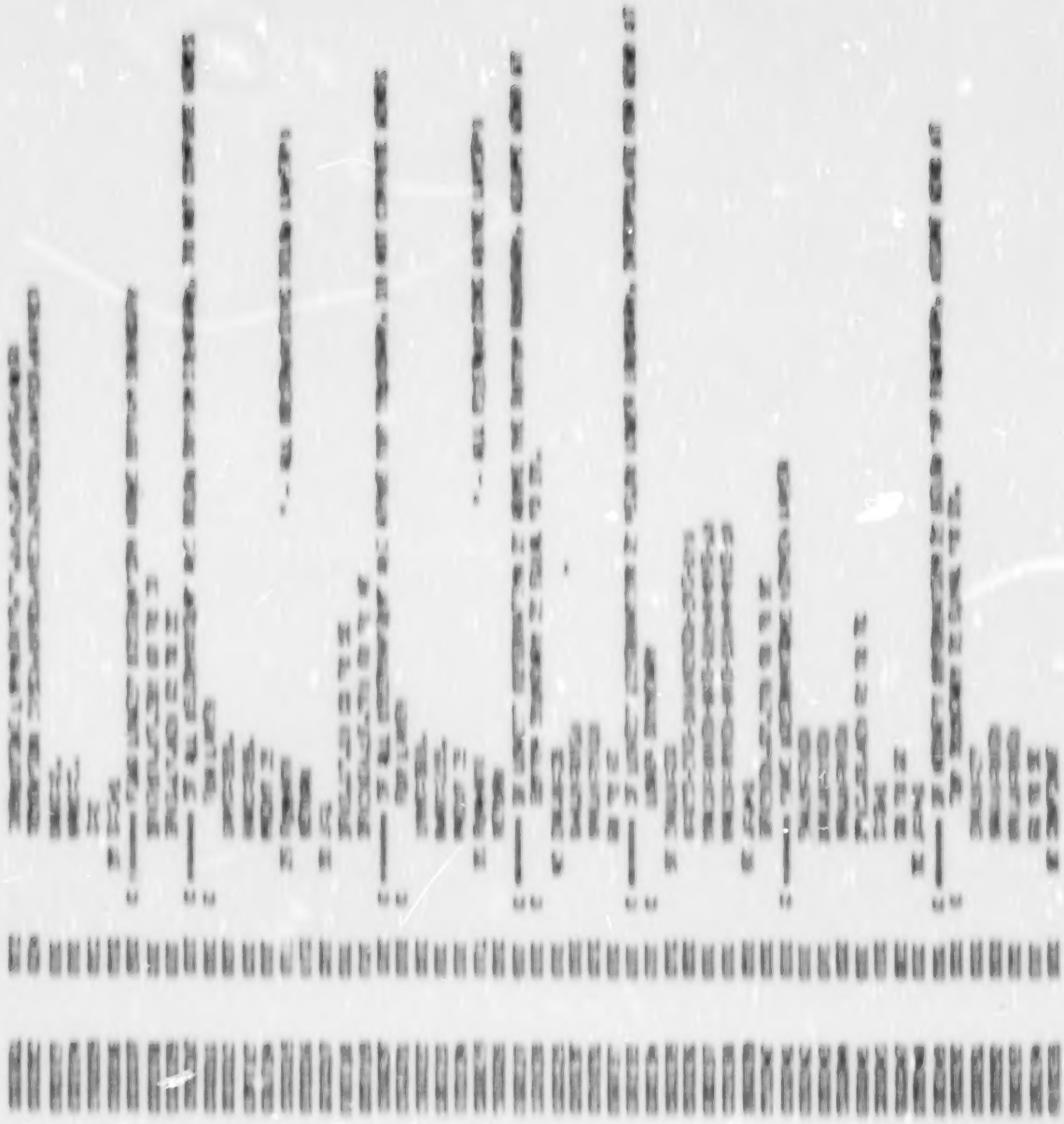
SOURCE PROGRAM LISTINGS

The complete listing of the Random-to-Grid and STRAN programs as used to produce the installation test run example of Section IV is given below.







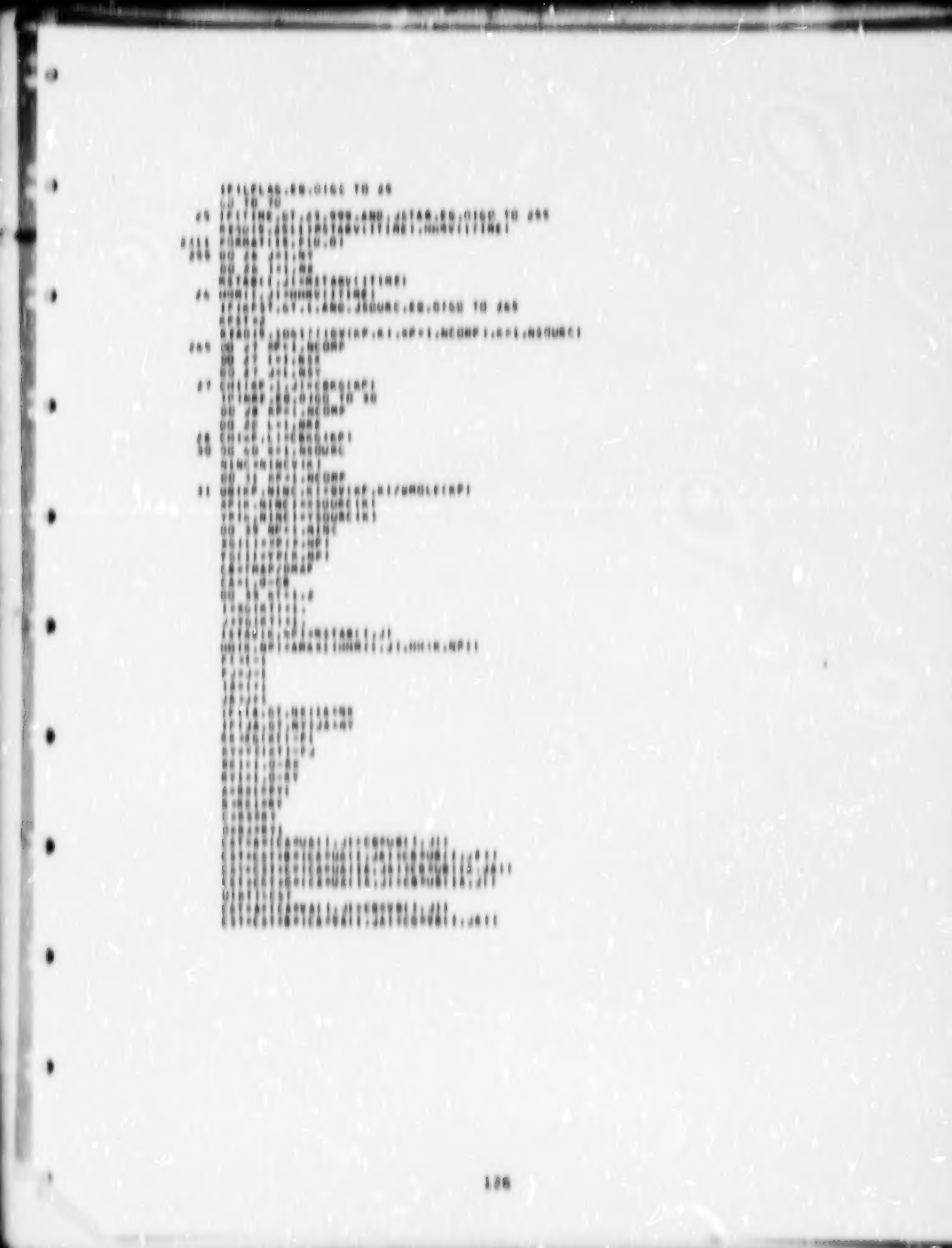


```
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE8,TAPE9)
      DIMENSION CHI(6,13,13),CHIMAX(6,13),CHIAVG(6,13),CHIAVG6(13
     1,13),SOURCE(10),YSOURCE(10),RECORD(6),RPOLUTE(13),MAXAVG(6)
      DIMENSION PASQUAL(7,13),UA(13),UR(13),VA(13,7),VR(13,7),U(13)
      DIMENSION UI(13),V(13),DELAT(6),DELT(6),RGIB(6),VGIB(6),GNOLE(7)
      DIMENSION XSI(13),KASTAV(13),SIGMAX(13),SIGAV(13),HMRV(6)
      DIMENSION XSE(10),YSE(10),YSOURCE(10),RELCONC(10),CNTR(10),CONMAX(10)
      DIMENSION CNSAVG(6,10),CNCAVG(6,10),AVG(6,10),SOALAT(10),SOALON(10)
      COMMON DISCV(10),SOTG,IOO,IOI,CONST(6),DELTA(100),VOUT(6,100),HI(10),
     1CONV(10),DELH(6,100),HMAX(6,100),SIGMAZ(6,100),PTHET(6,100),SHEET(6,1
     200),YSIGN(10,100)
      DIMENSION KST(6,17),HHH(17,3)
      INTEGER OPTION
      DATA KST/102
      PI=3.141592
      CONV=180./PI
      RCONV=PI/180.
      DELT=0.1666
C     XS IS DISTANCES BETWEEN PLUME INCREMENTS IN METERS.
C     DELMAX IS THE TIME LIMIT FOR THE RUN.
C     DELT IS THE TIME INCREMENT BETWEEN PLUME INCREMENTS.
C     NSOURC IS THE NUMBER OF SOURCES.
C     NGIND IS THE NUMBER OF WIND STATIONS.
C     NCOMP IS THE NUMBER OF CHEMICAL CONSTITUENTS USED IN ANALYSIS.
C     NXS IS THE NUMBER OF INTERSECTIONS IN THE X DIRECTION OF THE RNE GRID.
C     NYS IS THE NUMBER OF INTERSECTIONS IN THE Y DIRECTION OF THE RNE GRID.
C     NX IS THE NUMBER OF INTERSECTIONS IN THE X DIRECTION IN THE ANALYSIS.
C     NY IS THE NUMBER OF INTERSECTIONS IN THE Y DIRECTION IN THE ANALYSIS.
C     XLL AND YLL ARE THE COORDINATES OF THE LOWER LEFT CORNER OF THE GRID.
C        THE ORIGIN IS AT THE POLE, AND THE SPACING IS IN RNE GRID COORDINATES.
C     NSPACE IS THE NUMBER OF INCREMENTS OF SPACE BETWEEN X AND Y AXES.
C     ALL COORDINATES ENTERED ARE IN KM AND MAY HAVE THE ORIGIN AT THE LOWER LEFT.
C     THE Z-DIMENSION OF THE GRID IS THE SAME AS THE Y-DIMENSION IS THAT.
C     XSOURC AND YSOURC ARE THE COORDINATES OF NSOURC SOURCES.
C     XWIND AND YWIND ARE THE COORDINATES OF NGIND WIND LOCATIONS.
      READ(8,1000)OPTION
      READ(8,1000)NSOURC
      READ(8,1000)NGIND
      READ(8,1000)NCOMP
      READ(8,1000)(CONST(I),I=1,6)
      READ(8,1000)(VOUT(I,1),I=1,6)
      READ(8,1000)NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT
1001  FORMAT(8F10.0)
1002  FORMAT(16I5)
1003  FORMAT(8A10)
1005  FORMAT(2A10,8F10.0)
      DO 2 I=1,NSOURC
      READ(8,1005)SOURCE(I),YSOURCE(I),RELCONC(I),CNTR(I),CONMAX(I),
      1SOALAT(I),SOALON(I)
2     CONTINUE
      READ(8,1003)(WIND(I),I=1,NGIND)
      READ(8,1002)(KST(I),I=1,NGIND)
      READ(8,1000)(XWIND(I),I=1,NGIND)
      READ(8,1000)(YWIND(I),I=1,NGIND)
      READ(8,1000)(HI(I),I=1,NCOMP)
      READ(8,1000)(SIGMAZ(1,I),I=1,NSPACE)
      READ(8,1000)(PTHET(1,I),I=1,NSPACE)
      READ(8,1000)(SHEET(1,I),I=1,NSPACE)
      READ(8,1000)(SIGMAZ(2,I),I=1,NSPACE)
      READ(8,1000)(PTHET(2,I),I=1,NSPACE)
      READ(8,1000)(SHEET(2,I),I=1,NSPACE)
      READ(8,1000)(SIGMAZ(3,I),I=1,NSPACE)
      READ(8,1000)(PTHET(3,I),I=1,NSPACE)
      READ(8,1000)(SHEET(3,I),I=1,NSPACE)
      READ(8,1000)(SIGMAZ(4,I),I=1,NSPACE)
      READ(8,1000)(PTHET(4,I),I=1,NSPACE)
      READ(8,1000)(SHEET(4,I),I=1,NSPACE)
      READ(8,1000)(SIGMAZ(5,I),I=1,NSPACE)
      READ(8,1000)(PTHET(5,I),I=1,NSPACE)
      READ(8,1000)(SHEET(5,I),I=1,NSPACE)
      READ(8,1000)(SIGMAZ(6,I),I=1,NSPACE)
      READ(8,1000)(PTHET(6,I),I=1,NSPACE)
      READ(8,1000)(SHEET(6,I),I=1,NSPACE)
      READ(8,1000)(DELH(1,I),I=1,NSPACE)
      READ(8,1000)(DELH(2,I),I=1,NSPACE)
      READ(8,1000)(DELH(3,I),I=1,NSPACE)
      READ(8,1000)(DELH(4,I),I=1,NSPACE)
      READ(8,1000)(DELH(5,I),I=1,NSPACE)
      READ(8,1000)(DELH(6,I),I=1,NSPACE)
      READ(8,1000)(HMAX(1,I),I=1,NSPACE)
      READ(8,1000)(HMAX(2,I),I=1,NSPACE)
      READ(8,1000)(HMAX(3,I),I=1,NSPACE)
      READ(8,1000)(HMAX(4,I),I=1,NSPACE)
      READ(8,1000)(HMAX(5,I),I=1,NSPACE)
      READ(8,1000)(HMAX(6,I),I=1,NSPACE)
      READ(8,1000)(SIGMAX(I),I=1,NSPACE)
      READ(8,1000)(SIGAV(I),I=1,NSPACE)
      READ(8,1000)(HMRV(I),I=1,6)
      READ(8,1000)(KASTAV(I),I=1,NSPACE)
      READ(8,1000)(VGIB(I),I=1,6)
      READ(8,1000)(RGIB(I),I=1,6)
      READ(8,1000)(DELAT(I),I=1,6)
      READ(8,1000)(GNOLE(I),I=1,7)
      CALL INPUT(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE INPUT(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PRINT(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE CONC(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT1(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT2(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT3(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT4(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT5(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT6(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT7(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT8(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
      SUBROUTINE PLOT9(NSOURC,NGIND,NCOMP,NXS,NYS,NX,NY,NSPACE,DELMAX,DELT,DSAMP,DPRINT,
     1SOURCE,YSOURCE,RELCONC,CNTR,CONMAX,SOALAT,SOALON,WIND,KST,XWIND,YWIND,
     2HI,SIGMAZ,PTHET,SHEET,DELH,HMAX,SIGMAX,SIGAV,HMRV,KASTAV,VGIB,RGIB,
     3DELAT,GNOLE,XLL,YLL,XUR,YUR,DIV
      RETURN
      END
```

```
      XSUB=(XSUB-SW(1))*DIV
      YSUB=(YSUB-YLL)*DIV
      NSB=XSUB*1.001
      NAV=YSUB*1.001
      NBI=NBB(1)*DIV
      NVI=NBV(1)*DIV
      NBB=NBI
      NBV=NVI
      NS=NSB*NAV
      NT=NBV*NBI
      IPAC=3600,*OUTPUT/DP
      READ(5,1000)IOPTION,MODC,FACTOR,XUSMIN,SUBMAS
      READ(5,1041)(BASISP(I,KP=1,NCOMP)
1041  FORMAT(8E10.0)
      READ(5,1001)(WMOLE(KP),KP=1,NCOMP)
      PMOLE=10.0**12
      DO 1042 KP=1,NCOMP
1042  (BASISP(I=(BASISP(I)/(PMOLE=WMOLE(KP))
      DO 109 KP=1,NCOMP
 109  READ(5,1005)(SPOLUT(KP,II,I=1,15)
      DO 11 K=1,NSOURC
      READ(5,1001)(SOBLAT(K),SOBLON(K),HIK)
      A=SOBLAT(K)/CONV
      B=SOBLON(K)/CONV
      R=SI,1000*(COS(A)*COS(A)*SIN(A))
      XNMC=-R*SIN(B-BIGHTY)
      YNMC=-R*COS(B-BIGHTY)
      XSOURC(K)=(XNMC-PLOAT(LLS))*PLOAT(IDIV)
 11   (SOURC(K)=(YNMC-PLOAT(LLY))*PLOAT(IDIV)
      IF(NSB.EQ.0)GO TO 13
      DO 115 L=1,NBB
      READ(5,1001)SOBLAT(L),SOBLON(L)
      A=SOBLAT(L)/CONV
      B=SOBLON(L)/CONV
      R=SI,1000*(COS(A)*COS(A)*SIN(A))
      XNMC=-R*SIN(B-BIGHTY)
      YNMC=-R*COS(B-BIGHTY)
      XBSOU(L)=(XNMC-PLOAT(LLS))*PLOAT(IDIV)
      YBSOU(L)=(YNMC-PLOAT(LLY))*PLOAT(IDIV)
      XBSOU(L)=XBSOU(L)-XLL*DIV
 115  YBSOU(L)=YBSOU(L)-YLL*DIV
 13   WRITE(6,1501)
1501  FORMAT(1H1,"SOURCE TRANSPORT DEPOSITION ANALYSIS MODEL")
      WRITE(6,1502)IOPTION,DTIME,DMAP,OPRINT
1502  FORMAT(1HO,"EQUAL TIME FOR RUN IS=F7.0," HOURS,"/1H ,"BASIC TIME I
     1NCREMENT IS=F7.0," HOURS,  MAP INTERVAL IS=F7.0," HOURS,"/1H ,"AVE
     2RAGING INTERVAL BETWEEN PRINTED CONTOUR SERIES IS=F8.1," HOURS")
      WRITE(6,1503)NSOURC
1503  FORMAT(1HO,"THERE ARE="I3," SOURCE LOCATIONS:")
      WRITE(6,1507)
1507  FORMAT(1H ,"     LATITUDE, LONGITUDE, X AND Y COORDINATES ON THE
     1 ADVECTION GRID, AND EFFECTIVE STACK HEIGHTS ARE:")
      DO 181 K=1,NSOURC
 181  WRITE(6,1511)(SOBLAT(K),SOBLON(K),XSOURC(K),YSOURC(K),HIK)
1511  FORMAT(1H ,8F10.2,F10.3,F10.3,F10.0," CM.")
      WRITE(6,1521)NCOMP
1521  FORMAT(1H0,I3," CHEMICAL COMPONENTS ARE ANALYZED.")
```

```
      WRITE(6,1000)(NMOLE(ISP),SP(I),NSCMP)
1000  FORMAT(10X,'MOLECULAR WEIGHTS ARE'/6F10.1)
      WRITE(6,1001)(BKGIRP),SP(I),NSCMP)
1001  FORMAT(10X,'BACKGROUND CONCENTRATIONS IN MOLE/CM**3'/6E13.6)
      WRITE(6,1002)
1002  FORMAT(10X,'THE GRID IS DERIVED FROM THE NMC GT BY GT GRID BY SELEC
     1TING A RECTANGULAR PORTION AND FURTHER SUBDIVIDING.')
      WRITE(6,1003)ILL,JLL
1003  FORMAT(10X,'THE COORDINATES ON THE NMC GRID OF THE LOWER LEFT CORN
     1ER OF THE RECTANGLE ARE'2I5,'.')
      WRITE(6,1004)
1004  FORMAT(10X,'THESE ARE SPECIFIED WITH RESPECT TO A RIGHT HANDED COO
     1RDINATE SYSTEM WITH THE ORIGIN AT THE POLE.')
      WRITE(6,1005)
1005  FORMAT(10X,'THE NEGATIVE Y AXIS EXTENDS DOWNWARD ALONG THE MERIDI
     1AN 80 DEGREES WEST.')
      WRITE(6,1006)IMAX1,JMAX1
1006  FORMAT(10X,'THE AREA OF THE RECTANGLE IS'I3,' BY'I3,' NMC GRID SQU
     1ARES.')
      WRITE(6,1007)IMAX1,MAX
1007  FORMAT(10X,'THIS AREA IS DIVIDED 'SUB'I3,' BY'I3,' SQUARES TO FORM
     1 THE ADVECTION GRID.')
      WRITE(6,1008)ILL,JLL,SUB,SUB
1008  FORMAT(10X,'THE COORDINATES ON THE ADVECTION GRID OF THE LOWER LEF
     1T AND UPPER RIGHT CORNERS OF THE SAMPLING GRID ARE'/1H ,8F6.1,' AN
     2D'2F6.1,' RESPECTIVELY.')
      WRITE(6,1009)SUB,SUB
1009  FORMAT(10X,'THE SAMPLING GRID IS DIVIDED INTO'F6.1,' BY'F6.1,' SQU
     1ARES')
      WRITE(6,1010)IMAX,MAX
1010  FORMAT(10X,'SINCE SAMPLING IS AT INTERSECTIONS THE SAMPLING MATRIX
     1 IS'I3,' BY'I3,'.')
      IF(NSC.EQ.0)GO TO 132
      WRITE(6,1011)NSC
1011  FORMAT(10X,'IN ADDITION THERE ARE'I3,' PARTICULARLY SPECIFIED SAMP
     1LING LOCATIONS.')
      WRITE(6,1012)
1012  FORMAT(10X,'     LATITUDES, LONGITUDES, X AND Y COORDINATES ON THE
     1 ADVECTION GRID ARE')
      DO 130 L=1,NSC
      WRITE(6,131)(ALAT(L),OLON(L),XREL(L),YREL(L)
131   FORMAT(10X,4F10.2,F30.2,F10.2)
      WRITE(6,1003)
1003  FORMAT(10X,'     X AND Y COORDINATES OF THE PARTICULAR LOCATIONS O
     1N THE SAMPLING GRID ARE')
      DO 133 L=1,NSC
      WRITE(6,131)(XREL(L),YREL(L)
      WRITE(6,132)OPTION,NODE,FACTOR,SUBDIV,SUBMAX
1007  FORMAT(10X,'THE STRAC PARAMETERS OPTION AND NODE ARE'2I6,',   FACT
     1OR IS'F5.1,',','/1H ,'SUBDIV AND SUBMAX ARE'2F10.0)
      A=PA/100000.
      B=PB/100000.
      WRITE(6,1234)A
1234  FORMAT(10X,'THE BASIC SQUARE LENGTH IN THE ADVECTION GRID IS'F7.2,'
     1 KM.')
      WRITE(6,1234)B
```

```
1501 FORMAT(1H ,"THE BASIC SQUARE LENGTH IN THE SAMPLING GRID IS",F7.0,"
     1 KM.")
     WRITE(6,1351)IHR,IDAY,IMON,IYEA
1551 FORMAT(1HO,"THE INITIAL TIME IS",I5,":",I5," (HOUR,DAY,MONTH,YEAR)")
     CALL DIAGNO(NSOURC,NCORP,NX,NY,NSX,NSY,LLX,LLY,XSOURC,YSOURC,PMX,P
    1MY,SMX,SMY,VMX,VSUR,YSUR)
     CALMAG=100.0
     SIINC=3600.0*DTIME
     IF(SUBMIN.GT.0.0)CALMAG=STIME/SUBMIN*0.05*CALMAG*SIINC
     WRITE(6,2)NSOURC,NCORP,LLX,LLY,NSX,NSY,IDIV,IHR,IDAY,IMON,IYEA,DPTIO
    1N,MODE
     WRITE(6,3)TLIMIT,DTIME,DMAP,XLL,YLL,XUR,YUR,DIV,DR,DRS,(XSOURC(I),YS
    1OURC(I),H(I),Q(I),I=1,NSOURC)
     WRITE(6,4)NMS,XSLAT,XSLON
     DO 15 KP=1,NCORP
     DO 13 J=1,NSY
     DO 11 I=1,NSX
     CONSAV(KP,I,J)=0.0
  13 CONLAV(KP,I,J)=0.0
     DO 15 N=1,NSOURC
     DO 15 NP=1,IMAX
     SIGYA(N,NP)=0.0
     SIGZA(N,NP)=0.0
     CMAX(NP)=0.0
     XIMAX(N,NP)=0.0
  15 CTIMAX(N,NP)=0.0
     CALL MAPFAC(PI,XLL,XLT,IDIV,FACMAP,MS,MT)
     CALL LATLON(XLL,XLY,IDIV,XLL,YLL,DIV,XSS,XSY,CHI,PII
  19 TIME=0.0
     TMAP=0.0
     TPRINT=0.0
     ITIME=0
     DEPLAG=0
     DO 20 I=1,NSOURC
  20 QINC(I)=0
  21 CALL CALCRD(IHR,IDAY,IMON,IYEA,DTIME,JHR,JDAY,JMON,JYEA)
     ITIME=ITIME+1
     IF(ITIME.GT.MOTCLA)ITIME=1
     IF(FIRST.NE.0)GO TO 22
     CALL WINDUA(YA,NSA,NSB,NYA,NYB,NBREAK,DPST,LFLAG,TIME,CALMAG)
     NSTART=NSB-NSA+1
     NYSTRT=NYB-NYA+1
     IF(NYSTRT.EQ.1)NYSTRT=NY
     IF(NYSTRT.EQ.NY)NYSTRT=1
     WRITE(6,2101)
2101 FORMAT(1HO,"DIMENSIONS ON WIND TAPE DISAGREE WITH THOSE CALCULATED
    1 FROM INPUT PARAMETERS")
     WRITE(6,2102)NSTRST,NS,NYSTRT,NY
2102 FORMAT(1H ,"NSTRST,NS,NYSTRT,NY=",4I5)
     STOP
  22 TMAP=TMAP+DTIME
     IF(TMAP.LE.DMAP)GO TO 23
     TMAP=0.0
     DO 23 I=1,NS
     DO 23 J=1,NY
     UA(I,J)=UA(I,J)
  23 VA(I,J)=VA(I,J)
  24 CALL WINDUA(YB,NSA,NSC,NYA,NYB,NBREAD,DPST,LFLAG,TIME,CALMAG)
```



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[illegible]
[illegible]
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      DO 44 KP=1,NCOMP
      IF(ICOMP(KP).EQ.0)GO TO 44
      WRITE(IP,1700)KP,(CHI(KP,I,J,1),I=1,NXS),J=1,NSY)
      IF(NRE.EQ.0)WRITE(IP,1701)(CHI(KP,I,1),I=1,NXS)
   42 CONTINUE
      DO 43 KP=1,NCOMP
      DO 43 J=1,NSY
      DO 43 I=1,NXS
      CHISAV(KP,I,J)=CHISAV(KP,I,J)*CHI(KP,I,J)*DIFINC
   43 CHI(KP,I,J)=CHI(KP,I,J)*CHI(KP,I,J)*DIFINC
      IF(NRE.EQ.0)GO TO 45
      DO 44 KP=1,NCOMP
      DO 44 I=1,NXS
      CHISAV(KP,I)=CHISAV(KP,I)*CHI(KP,I)*DIFINC
   44 CHI(KP,I)=CHI(KP,I)*CHI(KP,I)*DIFINC
   45 IF(IPRINT.EQ.0)GO TO 50
      CALL PRCHI(IRST,CHI,NXS,NSY,1,0,NCOMP,NRE,XXS,YXS,CH,JHR,JDAY,JMO
     1N,JYR,XPOLUT,PHOLE,BHOLE)
   50 IF(IPRINT.LT.0)PRINT*,'GO TO 60
      IPRINT=0.0
      DO 56 KP=1,NCOMP
      DO 56 J=1,NSY
      DO 56 I=1,NXS
   56 CHIMAX(KP,J)=AMAX1(CHIMAX(KP,J),CHI(KP,I,J))
      IF(NRE.EQ.0)GO TO 58
      DO 57 KP=1,NCOMP
      DO 57 I=1,NXS
   57 CHMAX(KP,I)=AMAX1(CHMAX(KP,I),CHI(KP,I))
   58 CALL PRCHI(IRST,CHISAV,NXS,NSY,OPRINT,NCOMP,NRE,XXS,YXS,CHSAV,
     1JHR,JDAY,JMON,JYR,XPOLUT,PHOLE,BHOLE)
   60 DO 61 KP=1,NCOMP
      SINCYR(KP)=INCYR(KP)
      IF(INCYR(KP).GT.IMAX)GO TO 65
   61 CONTINUE
      IF(TIME.LT.TLIMIT)GO TO 21
      GO TO 80
   65 WRITE(6,6500)INCYR
 6500 FORMAT(1HO,"ONE PLUME HAS TOO MANY INCREMENTS"I6I4)
      WRITE(6,6502)JHR,JDAY,JMON,JYR
 6502 FORMAT(1H ,"TIME OF TERMINATION IS"4I5," (HOUR,DAY,MONTH,YEAR)")
      WRITE(6,6503)TIME
 6503 FORMAT(1H ,"RUNNING TIME IS"F7.1," HOURS.")
      WRITE(6,6504)IMAX
 6504 FORMAT(1H ,"MAXIMUM ALLOWED NUMBER OF INCREMENTS PER PLUME IS"I6)
      TLIMIT=TIME
      GO TO 80
   70 WRITE(6,7001)
 7001 FORMAT(1HO,"END OF FILE ENCOUNTERED ON WIND TAPE")
      WRITE(6,6502)JHR,JDAY,JMON,JYR
      WRITE(6,6503)TIME
      TLIMIT=TIME
   80 CALL PRCHI(IRST,CHIMAX,NXS,NSY,OPRINT,NCOMP,NRE,XXS,YXS,CHMAX,
     1JHR,JDAY,JMON,JYR,XPOLUT,PHOLE,BHOLE)
      CALL PRCHI(IRST,CHISAV,NXS,NSY,TLIMIT,NCOMP,NRE,XXS,YXS,CHSAV,
     1JHR,JDAY,JMON,JYR,XPOLUT,PHOLE,BHOLE)
      ENDFILE 4
      WRITE(6,8001)
```

```
8001 FORMAT(1H0,'TAPE WRITTEN WITH EOF')
     STOP
     END
     SUBROUTINE DIAGNO(NSOURC,NRCOMP,NS,NT,NSS,NST,LLS,LLT,KSOURC,YSOURC
    1,YRS,YRT,NRS,NRT,XRS,XRT,XSOR,YSOR)
     DIMENSION KSOURC(10),YSOURC(10),XRS(10),YRS(10)
     IF(NSOURC.GT.0.AND.NSOURC.LE.10)GO TO 11
     WRITE(6,1001)NSOURC
1001 FORMAT(1H ,'NSOURC =',I5,';  10 IS UPPER LIMIT.')
     STOP
  11 IF(NRCOMP.GT.0.AND.NRCOMP.LE.6)GO TO 12
     WRITE(6,1101)NRCOMP
1101 FORMAT(1H ,'NRCOMP =',I5,';  6 IS UPPER LIMIT')
     STOP
  12 IF(NS.GE.0.AND.NS.LE.17)GO TO 13
     WRITE(6,1201)NS
1201 FORMAT(1H ,'NS =',I5,';  LIMITS ARE 1 AND 17')
     STOP
  13 IF(NT.GE.0.AND.NT.LE.15)GO TO 14
     WRITE(6,1301)NT
1301 FORMAT(1H ,'NT =',I5,';  LIMITS ARE 1 AND 15')
     STOP
  14 IF(NSS.GE.0.AND.NSS.LE.15)GO TO 15
     WRITE(6,1401)NSS
1401 FORMAT(1H ,'NSS =',I5,';  LIMITS ARE 1 AND 15')
     STOP
  15 IF(NST.GE.0.AND.NST.LE.15)GO TO 16
     WRITE(6,1501)NST
1501 FORMAT(1H ,'NST =',I5,';  LIMITS ARE 1 AND 15')
     STOP
  16 IF(LLS.GE.-25.AND.LLS.LE.15)GO TO 17
     WRITE(6,1601)LLS
1601 FORMAT(1H ,'LLS =',I5,';  LIMITS ARE -25 AND 15')
     STOP
  17 IF(LLT.GE.-25.AND.LLT.LE.-9)GO TO 170
     WRITE(6,1701)LLT
1701 FORMAT(1H ,'LLT =',I5,';  LIMITS ARE -25 AND -9')
     STOP
 170 KSFLAG=0
     KTFLAG=0
     LSFLAG=0
     LTFLAG=0
     DO 18 I=1,NSOURC
     IF(KSOURC(I).LT.0.0.OR.KSOURC(I).GT.XNSINSFLAG)
     IF(YSOURC(I).LT.0.0.OR.YSOURC(I).GT.YNTINTFLAG)
     IF(KSFLAG.NE.0)WRITE(6,1751)KSFLAG
     IF(KTFLAG.NE.0)WRITE(6,1752)KTFLAG
1751 FORMAT(1H ,'X COORDINATE OF SOURCE=',I5,' OFF ADVERTISING GRID')
1752 FORMAT(1H ,'Y COORDINATE OF SOURCE=',I5,' OFF ADVERTISING GRID').
  18 CONTINUE
     IF(NRC.EQ.0)GO TO 20
     DO 19 I=1,NRC
     IF(XRS(I).LT.0.0.OR.XRS(I).GT.XSUBILSFLAG)
     IF(YRS(I).LT.0.0.OR.YRS(I).GT.YSUBILTFLAG)
     IF(LSFLAG.NE.0)WRITE(6,1851)LSFLAG
     IF(LTFLAG.NE.0)WRITE(6,1852)LTFLAG
1851 FORMAT(1H ,'X COORDINATE OF RECEPTOR =',I5,' OFF SAMPLING GRID')
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1592 FORMAT(1H ,"Y COORDINATE OF RECEPTOR "I6," OFF SAMPLING GRID")
  10 CONTINUE
  88 IF(XSPCL.NE.0.0)XYFLAG=.NE.DISTOF
     IF(YSPCL.NE.0.0)LYFLAG=.NE.DISTOF
  99 RETURN
     END
     SUBROUTINE CALENDO(JHR,JDAY,JMON,IYER,OTIME,JHR,JDAY,JMON,JYEAR)
     DIMENSION NDAYIE)
     DATA NDAY/31,28,31,30,31,30,31,31,30,31,30,31/
     DATA OPST/0/
     IF(OPST.NE.0)GO TO 8
     OPST=1
     IYER=IYEAR/4
     IF(4*IYER.EQ.IYEAR)NDAY(2)=29
     JHR=1
     JDAY=1DAY
     JMON=1MON
     JYER=1YER
   8 TIME=OTIME+0.01
     JHR=JHR+1
     IF(JHR.LT.25)RETURN
     JHR=JHR-24
     JDAY=JDAY+1
     IF(JDAY.LE.NDAY(JMON))RETURN
     JDAY=1
     JMON=JMON+1
     IF(JMON.LE.12)RETURN
     JMON=1
     JYER=JYER+1
     IF(NDAY(2).EQ.28)GO TO 9
     NDAY(2)=28
     RETURN
   9 IYER=(JYER/4)
     IF(4*IYER.EQ.JYER)NDAY(2)=29
     RETURN
     END
     SUBROUTINE PRCNTI(TITLE,S,NSR,DAY,OUTIME,NECORP,NRC,SREC,YREC,Y,JHR
    1,JDAY,JMON,JYER,APOLUT,PMOLE,WMOLE)
     DIMENSION LTITLE(131),A(2,13),IS(13),SREC(101),YREC(101),Y(6,101),APOLUTIO
    1,13),WMOLE(6)
     DO 9 NC=1,NECORP
     WRITE(6,1001)LTITLE
1001 FORMAT(1H1,131A1)
     WRITE(6,1002)IN,(APOLUTION,II,I=1,13)
1002 FORMAT(10 ,15,5X,13A6," MICROGRAMS/CUBIC METER")
     WRITE(6,1003)JHR,JDAY,JMON,JYER
1003 FORMAT(1H ,"TIME AT END OF INTERVAL="I5," (HOUR,DAY,MONTH,YEAR)")
     NC=0.0
     CINFAC=PMOLE*WMOLE(N)/OVTIME
     DO 5 J=1,NSY
     JR=NSY+1-J
     IF(OVTIME.EQ.1.0)GO TO 8
     DO 2 I=1,NSR
   2 A(N,I,JR)=A(N,I,JR)*CINFAC
   5 WRITE(6,1001)(A(N,I,1),I=1,NSR)
1001 FORMAT(1H0,13P10.3)
     DO 6 I=1,NSR
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```
      MC=AMAX1(MC,SIN(I,J))
      SIN(I,J)=0.0
  600 FORMAT(1X,'NO.=MAXIMUM ELEMENT IN MATRIX IS=',F10.3)
      CONTINUE
      WRITE(6,600)MC
      IF(MC.GE.0.0)GO TO 9
      WRITE(6,5001)
 5001 FORMAT(1H ,'ERROR: NO MILAN FIGURES FOR PARTICULAR RECEPTOR SITES')
      DO 6 I=1,NRS
    6 SIN(I,J)=SIN(I,J)/MC
      WRITE(6,5002)((SIN(I,J),I=1,NRS),J=1,NRS)
 5002 FORMAT(1HO,'R E C E P T O R  C O N C E N T R A T I O N S  ON SAMPLING GRID=',10F9.3)
      WRITE(6,7001)((SIN(I,J),I=1,NRS),J=1,NRS)
 7001 FORMAT(1H ,'  C O N C E N T R A T I O N S  ON SAMPLING GRID=',10F9.3)
      WRITE(6,8001)((SIN(I,J),I=1,NRS),J=1,NRS)
 8001 FORMAT(1HO,'CONCENTRATIONS=',F10.3,9F10.3)
      DO 99 I=1,NRS
      SIN(I,I)=0.0
    9 CONTINUE
      RETURN
      END
      SUBROUTINE MAPFAC(PI,LLS,LLY,IDIV,FR,NS-NY)
      DIMENSION SMIL(13)
      DIV=IDIV
      SINGS=SIN(PI/3.)
      DO 1 J=1,NY
      TC=FLOAT(J)*SINGS/FLOAT(J)=1.01/DIV
      DO 1 I=1,NS
      XC=FLOAT(I)+0.5*FLOAT(J)=1.01/DIV
      RSQUARE=XC*XC+YC*YC
      SMIL(I)=SQRT(RSQUARE)*FR
    1 PRINT 2,I,J,XC,YC,SMIL(I)
      WRITE(6,1001)
 1001 FORMAT(1HO,'MAP FACTORS=')
      DO 4 J=1,NY
      K=NS-I+1
    4 WRITE(6,2001)(SMIL(I),I=1,NS)
 2001 FORMAT(1H ,20F6.3)
      RETURN
      END
      SUBROUTINE LATLON(LLS,LLY,IDIV,ILL,YLL,DIV,RNS,RNY,CHI,PI)
      DIMENSION CHI(13,13)
      CONV=180./PI
      XL=FLOAT(LLS)+0.5*(1./FLOAT(IDIV))
      YL=FLOAT(LLY)+0.5*(1./FLOAT(IDIV))
      ORI=1.0/(1.0*FLOAT(IDIV)*1.0)
      DO 1 J=1,RNY
      YY=YL-0.5*FLOAT(J)+1.01
      DO 1 I=1,RNS
      XX=XL+0.5*FLOAT(I)+1.01
      CHI(I,J)=ATAN2(YY,XX)*CONV
    1 CHI(I,J)=360.0-CHI(I,J)+ORI
 1101 FORMAT(1H1,'LATITUDE AND LONGITUDE FOR SAMPLING GRID INTERSECTIONS')
      DO 8 J=1,RNY
```

```
      DO 9001 I=1,4
      WRITE(6,1000)(((I,J,K,L,M,N),L=1,5),M=1,5),N=1,5)
1001  FORMAT(100(1X,I3))
      WRITE(6,1000)(((I,J,K,L,M,N),L=1,5),M=1,5),N=1,5)
1002  FORMAT(1H ,100F10.2)
      CONTINUE
      DO 1 K=1,5
      DO 1 J=1,5
      DO 1 I=1,5
    1 C(I,J,K)=0.0
      RETURN
      END
      SUBROUTINE GINDEX(A,NA,NB,NC,NA,NY,NBLOCK,NT,I,J,K,L,M,N,IER,CALLNAME)
      DIMENSION A(1),NA(1),NB(1),NC(1),NA(1),NY(1),NBLOCK(1)
      DO 10 I=1,NA(1)
      DO 10 J=1,NB(1)
      DO 10 K=1,NC(1)
      DO 10 L=1,NA(1)
      DO 10 M=1,NY(1)
      DO 10 N=1,NBLOCK(1)
      IF(IER.EQ.0)GO TO 11
      WRITE(6,1001)I,J,K,L,M,N,IER,CALLNAME
1001  FORMAT(1H ,6I12,A6)
      RETURN
   11 CONTINUE
      IF(I.GT.NA(1))IER=1
      IF(J.GT.NB(1))IER=2
      IF(K.GT.NC(1))IER=3
      IF(L.GT.NA(1))IER=4
      IF(M.GT.NY(1))IER=5
      IF(N.GT.NBLOCK(1))IER=6
      IF(IER.EQ.0)GO TO 12
      WRITE(6,1000)I,J,K,L,M,N,IER,CALLNAME
1000  FORMAT(1H ,6I12,A6)
      STOP
   12 CONTINUE
      RETURN
      END
      SUBROUTINE GINDEX(A,NA,NB,NC,ND,NY,NBLOCK,NT,I,J,K,L,M,N,IER,CALLNAME)
      DIMENSION A(1),NA(1),NB(1),NC(1),ND(1),NY(1),NBLOCK(1)
      DO 10 I=1,NA(1)
      DO 10 J=1,NB(1)
      DO 10 K=1,NC(1)
      DO 10 L=1,ND(1)
      DO 10 M=1,NY(1)
      DO 10 N=1,NBLOCK(1)
      IF(IER.EQ.0)GO TO 11
      WRITE(6,1001)I,J,K,L,M,N,IER,CALLNAME
1001  FORMAT(1H ,6I12,A6)
      RETURN
   11 CONTINUE
      IF(I.GT.NA(1))IER=1
      IF(J.GT.NB(1))IER=2
      IF(K.GT.NC(1))IER=3
      IF(L.GT.ND(1))IER=4
      IF(M.GT.NY(1))IER=5
      IF(N.GT.NBLOCK(1))IER=6
      IF(IER.EQ.0)GO TO 12
      WRITE(6,1000)I,J,K,L,M,N,IER,CALLNAME
1000  FORMAT(1H ,6I12,A6)
      STOP
   12 CONTINUE
      RETURN
      END
      SUBROUTINE PLANE(IUU,N,VIRTH,E,NP)
      DIMENSION UU(10,100),NI(10),VIRTHI(10,100)
      VIRTHI=.9P10**10
      RETURN
      END
      SUBROUTINE STRACIN,SUBMIN,SUBMAS,FACTOR,MODE,TIME,OPTION,6888)
      COMMON ANTI01,SUBIA,IOC,IOI,CPRO(6),DST(10,100),DT(0,100),NT(10),
     1(CMT(10,100),CRMOIT,100,6),I,STAR(10,100),MM(10,100),SP(10,100),
     2VP(10,100),EP(10,100),STCRT(10,100),PTIME(10,100),REST(10),
     3VAZ(11)I,VIRTHI(0,100)
      DIMENSION VOIA(),WOC(6)
      DIMENSION AO(6),AV(6),CAIN(6),BB(6),COP(6),YOUM(10,100)
      INTEGER OPTION
1000  FORMAT(1H ,12F10.0)
```

```
      END
      SUBROUTINE
      DO 10 K=1,KKK
      GAININ(K)=0.
      ADJK(K)=0.
   10 AMIN(K)=0.
      TOTAL=0.
C     SETTING OF INITIAL STEP SIZE
      IF (MODE.EQ.1) STOP(IN,N)
      IF (MODE.EQ.2) GO TO 200
      DDS=DSIN(N)
      IF(SUBMIN.LT.DSIN(N)) DDS=SUBMIN
  100 TH=DDS
      C=XMIN(N)+0.0005
      CALL SIGMAZ(SIGY,SIGZ,N,N)
      DO 11 K=1,KKK
C     COMPUTATION OF VIRTUAL SOURCE STRENGTHS ON HALF INTERVAL
   11 QUTIN(=QUIK,N,N)=(ADJK(K)+AMIN(K)-GAININ(K))*0
      IF(QUTIN(K).LT.0.)QUTIN(K)=0.0
      IF(MODE.EQ.2) GO TO 140
      CALL INTSRF(OPTION,WET,DR,T,HR,SIGY,SIGZ,N,N,KKK,GAINI
      IF(MODE.EQ.3) GO TO 210
C     CALCULATION OF WASHOUT AND DRY DEPOSITION FLUXES
  145 CALL WSHOUT(N,WIC,N,KKK,TIME)
      CALL DRYDEP(N,VD,N,KKK,TIME)
      DO=VIRTUAL(N)*SQRT(2.*SIGZ*SIGZ)
      DO 367 K=1,KKK
      IF(OPTION.EQ.3) GO TO 366
      ADJK(K)=0.0
      IF(U.LE.30.0.AND.K.EQ.1)0079=QUTIN(K)*VDIN(K)*EXP(-USI*DO/(SIGZ*U))*(1.-EXP(-USI*DDS/(SIGZ*U)))
      GO TO 367
  366 ADJK(K)=QUTIN(K)*VDIN(K) /(U(N,N)*HMIN(N))
  367 AMIN(K)=WDEP(K)=QUTIN(K)*DDS/U(N,N)
C     CALCULATION OF VIRTUAL SOURCE STRENGTHS AT INTERVAL END
  210 DO 211 K=1,KKK
      QUPIN(K)=QUIN(K,N,N)-ADJK(K)-ADJK(K)*GAININ(K)
      IF(QUPIN(K).LT.0.)QUPIN(K)=0.0
  211 QUIN(K,N,N)=QUPIN(K)
  200 ***DDS/2.
C     PROVISION FOR X GRID SPACE ADJUSTMENT
      TOTAL=TOTAL+DDS
      SUMC=DSIN(N)-TOTAL
      IF(SUMC.LT.-.0011 GO TO 555
      DDSOLD=DDS
      DDS=DDS*FACTOR
      IF(DDS.GT.SUBLAS) DDS=DDSOLD
      IF(SUMC.LT.DDS) DDS=SUMC
      GO TO 123
C     CALCULATION OF GROUND LEVEL CONCENTRATIONS
  555 CALL SIGMAZ(SIGY,SIGZ,N,N)
      DY=SIGYZ.
      IF(OPTION.EQ.2) GO TO 666
      TH=VIRTUAL(N)+2.*(TH-.5*SIGZ)
      DO 650 K=1,KKK
      CON(K,N,N)=(3.14159*SIGY*SIGZ*U(N,N))
      DO 650 I=1,I
      YOUNT(N)=FLOAT(I-1)*DY
```

```
      SUBROUTINE INTGRT(OPTION,GOF,DX,TIME,SIGY,SIGZ,H,K,KMX,GAIN)
      COMMON ANN1(10),QUIK,IOC,IQT,CHECK(6),DELTA(10),IOUT,UTIL(10),ANT(6),
     1ICONT(10),IOC1,CCONST,IOC2,CI(15),AB(10),QQQ(10),MM(10,10),RZ(10,10),
     2TP(10,10),IZM(10,10),DTCAP(10,10),PTIME(10,10),RHOI(10,
     3YHAT(10,10),YATM(10,10)
      DIMENSION OPTION(6),AY(10),PYM(10,10)
      DIMENSION PYM(10,10),ZT(10),CAIM(6),C(6)
      INTEGER OPTION
      DATA QZ
     1   ,
     1   ,
     1   ,
     DATA ZERO/
     1   1.000000000000,     0.000000000000,     0.000000000000,
```

```
      SUBROUTINE SIGMA1(A,SIGT,SIGA,M,N)
      COMMON NINCV(10),QQ(6,10),QQ(10),QI(6,10),QI(10),QQ(10),QI(10),
```

```
PTSOT
CUPTSO
ASCII
ATSCI
CASCI
BTSCI
* CONTINUE
RETURN
END
SUBROUTINE LOINIPS(PY,SS,DT,SSO,DBS,DS,CY,DS,DY,S,PI
CHTSCRZTOL
C*COT=PT/TCS=PSI
JI=-1.0/3
CP=CHTV(I);C/(I,CPTSTRSII
SP=CHTV(I);C-(SSCP)
IP(SI.LT.C.0)SI=SP
CPSTRSI=0
CHTV=CHTSP
CASCI=-DBS
CTSCI=DCY
CS=DCY*DSY
CTSCTSCY
RETURN
END
```

SECTION VI

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SECTION VII

STRAM GLOSSARY

AD - Vector of loss rates of material from a plume segment due to dry deposition, mole/sec

AW - Vector of loss rates of material from a plume segment due to wet deposition, mole/sec

CA = 1.0 - CB.

CB - Fraction of map interval DMAP between time when last map was read in and end of current advection interval DTIME.

CGRND - Ground level concentration matrix computed in subroutine STRAC in coordinate system along the plume increment axis (crosswind position, increment, chemical component), moles/cm^3*

CH - Matrix of concentrations for particularly specified sampling sites averaged over the basic advection interval DTIME, printed as µgm/m^3

CHI - Matrix of griddnd concentrations averaged over the basic advection interval DTIME, typically one hour, printed as µgm/m^3, written to tape as gram mole/cm^3

CHIAV - Matrix of gridded concentrations averaged over the total running time TLIMIT, printed as µgm/m^3

CHIMAX - Matrix of maximum values over all matrices CHISAV, printed as µgm/m^3

CHISAV - Matrix of gridded concentrations averaged over the intermediate time interval DPRINT, which is typically 24 hours, printed as µgm/m^3

CHIAV - Matrix of particular point concentrations averaged over the total running time TLIMIT, printed as µgm/m^3

CHMAX - Matrix of maximum values over all vectors CHSAV, printed as µgm/m^3

CHSAV - Matrix of particular point concentrations averaged over the intermediate time interval DPRINT, printed as µgm/m^3

DDS - Subinterval of major downwind grid increment (DS) used for Runge-Kutta integration procedure, cm

DDSOLD - Previous value of DDS, cm

DIV - Linear subdivision factor between the sampling grid and the advection grid.

*Read in as µgm/m^3

DH - Interval between consecutive grid intersection on the advection grid at latitude 60°N, cm

DHAP - Time between successive gridded wind maps, hr

DHS - Interval between consecutive grid intersection on the sampling grid at latitude 60°N, cm

DPRINT - Time of the intermediate interval over which concentrations are averaged--the standard interval between concentration matrix printouts, hr

DS - Interval traversed by a plume increment during a basic advection step--matrix (source, increment), cm

DTIME - Time of the basic interval used for trajectory calculation--also the shortest interval over which concentrations are averaged, hr

DSYDX, DSZDY - Derivatives with travel distance of SIGMY and SIGMZ, respectively,

DX - Downwind distance increment for Runge-Kutta integration, cm

FACTOR - Ratio by which the interval of the integration along the plume axis in Subroutine STRAC is increased from one step to the next within the same basic advection step,

FMOLE - $(10^6$ μgm/gm)/$(10^{-6}$ m^3/cm^3) - conversion factor,

FUN - Rate of chemical reaction (dummy variable), moles/cm^3 sec

FUNCT - Rate of chemical reaction, moles/cm^3 sec

GAIN - Gain of material in plume segment by chemical reaction, moles/sec

H - Height vector for the plume sources, cm

HH - Nondecreasing mixing height applying to a particular plume segment, drawn from the gridded mixing height matrix HHM according to plume location,

HHM - Matrix of gridded mixing heights, cm

HHMV - Vector of mixing heights sufficient for one 24-hour cycle--one for each interval DTIME, cm

IDAY - Initial day of the run, in time zone of the wind tape,

IDIV - Linear subdivision factor between the advection grid and the 47 x 47 HHM grid,

IHR - Initial hour of the run in time zone of the wind tape,

IYER - Initial year of the run minus 1900,

IMAX - maximum number of increments allowed for each plume,

IMON = Initial month of the run.

JDAY = Current day within the run in the time zone of the wind tape.

JHR = Current hour within the run in the time zone of the wind tape.

JIAR = Current year minus 1900 within the run.

JMON= Current month within the run.

JSOURC = Option allowing one set of source strengths to serve as constants for an entire run. 0 = read in one set of source strengths; 1 = read in new source strengths at every interval DTIME.

JSTAB = Option allowing one 24-hour cycle of stabilities and mixing heights to be repeated diurnally throughout the entire run. 0 = read in one 24-hour cycle of stabilities and mixing heights, one set of two numbers at each interval DTIME; 1 = read in new values at interval DTIME throughout the entire run.

JYEAR = Current year within the run minus 1900.

KCOMP = A vector for six integers either 0 or 1, determining which of the six chemicals will be represented by average concentrations over the interval DTIME on the output tape.

KK = Chemical component index with a value of 1, 2, 3, 4, 5, or 6.

KPOLLUT = Alphameric matrix of names for the NCOMP chemical components under analysis. Each pollutant name is a vector.

KPRINT = Option governing printout of concentration values averaged over interval DTIME. 0 = omit; 1 = print.

KSTAB = The stability applying to a particular plume segment, drawn from the gridded stability matrix MSTAB according to the location of the plume.

KXI = Alphameric title vector for the matrix CHI.

KXILAV = Alphameric title vector for the matrix CHILAV.

KXIMAX = Alphameric title vector for the matrix CHIMAX.

KXISAV = Alphameric title vector for the matrix CHISAV.

LLX, LLY = X and Y coordinates on the UMC 47 x 47 grid of the lower left corner of the advection grid, counted from an origin at the pole. X is positive to the right, and Y is positive toward the top of the grid.

MODE - Dictates calculation sequence in Subroutine STRAC:
MODE = 1 - neither kinetics or deposition are calculated
MODE = 2 - deposition calculated
MODE = 3 - kinetics calculated
MODE = 4 - kinetics and deposition calculated

MRX, MRY - X and Y coordinates on the NMC 47 x 47 grid of the upper right corner of the advection grid, counted from an origin at the pole. X is positive to the right, and Y is positive toward the top of the grid.

MSTAB - Matrix of gridded stability (1, 2, 3, 4, 5, 6 according to Pasquill categories).

MSTABV - Vector of stabilities (integers 1-6 for Pasquill A-F) sufficient for one 24-hour cycle - one number for each interval DTIME.

NCOMP - Number of chemical components involved in the chemical analysis.

NINCV - The vector indicating the number of increments of each plume currently on the advection grid.

NP - Index for plume increments.

NRR - Option indicating whether or not sampling will be done at particular receptor sites on the grid, in addition to grid intersections

NSOURC - Number of plume sources.

NSX, NSY - Numbers of intersection in the horizontal and vertical directions, respectively, on the sampling grid.

NX, NY - Numbers of intersections in the X and Y directions, respectively, on the advection grid.

OPTION - An inter-option indicating whether vertical distribution will be considered (1) Gaussian with no lid limitations or (2) even between the surface and a lid.

PTIME - Total travel time for plume increments--matrix (source, increment), hr

QQ - Source strength matrix (chemical component, source, increment), moles/sec

QQF - Dummy array for source strengths, moles/cm^3

QQX - Dummy array for source strengths, moles/cm^3

QV - Matrix of source strengths (component, source) of emission at one interval DTIME, or by option for the entire run gm/sec

RELAT, RELON - Vectors of latitude and longitude, respectively, for the particularly specified sampling locations.

SIGMY, SIGMZ - Lateral and vertical standard deviation (σ_y, σ_z), respectively, at a point along the plume axis--matrices (source, increment). cm

SORLAT, SORLON - Latitude and longitude vectors, respectively, for the plume sources.

SUBMAX - Maximum interval of integration along plume axis in Subroutine STRAC. cm

SUBMIN - Minimum interval of integration along plume axis in Subroutine STRAC. cm

TIME - Time between the initial time of the run and the initial time of the current basic advection interval. hr

TLIMIT - Total time of a run. hr

TMAP - Time counter incremented between values of zero and DMAP at which value new wind maps are read in. hr

TOTAL - Distance from last emitted end of plume segment centerline to end of current integration interval. cm

TPRINT - Time counter incremented between values of zero and DPRINT, at which value the average concentration matrices CHISAV and CHSAV are printed out. hr

UU - Average wind speed for a plume increment during a basic advection step--matrix (source, increment). cm/sec

VD - Deposition velocity--vector (chemical component). cm/sec

W - Vector of weighting factors in Gauss-Laguerre integration.

WHOLE - Vector of molecular weights for the six chemical components. gm/mole

WOC - Washout rate--vector (chemical component). sec^{-1}

X - (in Subroutine PRCHI) Printed matrix of gridded concentrations. $\mu gm/m^3$

XC - Total travel distance for midpoint of a given plume increment. m

XLL, YLL - X and Y coordinates on the advection grid of the lower left corner of the sampling grid. The origin of the advection grid is at the lower left corner of the advection grid.

XM - Total travel distance for plume increments--matrix (source, increment). cm

XP, YP - X and Y coordinates on the advection grid of the plume increments--matrices (source, increment).

XREC, YREC - Vectors of X and Y coordinates on the advection grid of particular receptor locations.

XSOURC, YSOURC - Vectors of X and Y coordinates on the advection grid for the plume sources.

XUR, YUR - X and Y coordinates on the advection grid of the upper right corner of the sampling grid. The origin of the advection grid is at the lower left corner of the advection grid.

Y - (in Subroutine PRCNI) Printed concentrations of particular receptor locations, $\mu gm/m^3$

ZIKFAL - Conversion factor from $mole\text{-}hr/cm^3$ to $\mu gm/m^3$.

ZINT - Integral returned by Gauss-Laguerre integration subroutine (dummy variable).

ZLAGR - Transformed independent variable for Gauss Laguerre quadrature.

SECTION VIII

ADDENDA

A. CALM WINDS AND RELATION TO PARAMETER SUBMIN (page 40)

Each set of wind component matrices is edited so that wind speeds are never less than an arbitrary value defined in the code by CALMWD. Presently its value is set at 100 cm/sec. Such a provision is necessary because Subroutine STRAC executes an infinite loop if the advection over interval DTIME is less than the value of SUBMIN. If a wind speed is found to be less than CALMWD but greater than zero, the prevailing wind direction is used. Otherwise a direction is assigned.

B. CONSTRAINT ON DRY DEPOSITION CALCULATION (page 43)

The present algorithm for computation of dry deposition is not suited to computations for ground level releases if Gaussian vertical distribution is assumed (OPTION = 1) under very stable conditions.

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